Hospital Library
Wahr

SURGERY
GYNECOLOGY AND OBSTETRICS
An International Magazine, Published Monthly

VOLUME 81 JULY, 1945 NUMBER 1

PRIMARY RESECTION (CLOSED ANASTOMOSIS) OF RECTAL AMPULLA FOR MALIGNANCY WITH PRESERVATION OF SPHINCTERIC FUNCTION

Together with a Further Account of Primary Resection of the Colon and Rectosigmoid and a Note on Excision of Hepatic Metastases

OWEN H. WANGENSTEEN, M.D., F.A.C.S., Minneapolis, Minnesota

SOMEWHAT more than 2 years ago, the results in this clinic of primary resection of the colon without antecedent, complemental, or supplemental colostomy, save in the presence of acute obstruction were set forth (34). At the same time, a preliminary report was made upon efforts directed at salvage of sphincteric function in the radical abdominal operation for carcinoma of the rectal ampulla.

It is the writer's intent in this paper to report upon the experience of this clinic with the surgery of colonic malignancy since the time of the earlier report (April, 1943) and to elaborate particularly upon a more extended experience with the operation for carcinoma of the rectal ampulla with attempts at preservation of sphincteric function. Whereas experience with this latter operation still has been small, nevertheless, it has been adequate to indicate that, in suitable cases, radical excision of the lesion with preservation of sphincteric function is a feasible and practical procedure.

From the Department of Surgery, University of Minnesota, Minneapolis.

The researches presented here were supported by grants of the Augustus L. Searle Fund for Experimental Surgical Research, the Citizen's Aid Society, the Rosenblatt Fund for Cancer Research, and the Graduate School of the University of Minnesota.

Presented at the Meeting of the Western Surgical Association, December 2, 1944.

HOSPITAL MORTALITY IN PRIMARY RESECTION OF COLON AND RECTOSIGMOID

The earlier report referred to above embraced a 2 year period, during which time 61 patients underwent colonic resection with 1 hospital death. During the 19 month interval which has elapsed since that report (April, 1943 to November 1, 1944), an additional 78 patients have undergone resection of the colon including the rectosigmoid. All were primary resections, save 2, in which exteriorization was done. One of these had a volvulus of the pelvic colon; the other, an inflammatory lesion in the transverse colon. There were 6 deaths in the group, 3 of which are classified as unavoidable, 2 the result of peritonitis, and 1 of pneumonia.

Avoidable deaths. In 1 of these patients, primary resection was undertaken at the time

TABLE I.—HOSPITAL MORTALITY

	A. Primary Resection Colon and Rectosigmoid				B. Ampullary Resection			
	No. of patients	Hospital deaths	Mortality Per cent	Unavoidable deaths	No. of patients	Hospital deaths	Mortality Per cent	Unavoidable deaths
Series I 4-I-1941 to 4-I-1943	61	1	1.6	0	7	1	14.2	0
Series II 4-I-1943 to 11-I-1944	78	6	7.6	3	20	1	5.	1
Total	139	7	5.		27	2	7.4	
Combined (colon & rectum)	166	9	5.4					

of decompression of the colon for acute obstruction. This patient had a malignant growth in the pelvic colon with great distention. It obviously was a mistake in this instance to have undertaken decompression of the colon and primary anastomosis at the same time. The success of primary resection without antecedent or complemental colostomy in the earlier series suggested that it might be feasible to deal with the obstructed colon in the manner in which the obstructed small bowel is managed at operation by aseptic decompression suction enterotomy (32). Upon decompression the edematous walls of the obstructed colon, however, appear to separate into layers, making suture somewhat difficult. This occurrence was noted too in a subsequent case, in which primary resection of the pelvic colon was undertaken soon after spontaneous decompression of an enormously distended colon.

The other death from peritonitis occurred in a patient with a dubiously operable lesion, adherent to the urinary bladder, and the anterior as well as the posterior abdominal wall. In the light of the extensive operation undertaken in this patient, it might have been well to have made a complemental colostomy. Obviously, in the case of the patient with the acute obstruction an antecedent colostomy should have been carried out.

One of the avoidable deaths requires special comment; it occurred in an obese elderly man with carcinoma of the transverse colon, who also had a moderately active diverticulitis of the pelvic colon causing some symptoms. Primary resection of the transverse colon was done, the patient dying of pneumonia. In this patient, an exteriorization operation probably would have been tolerated better; it too would have been better treatment for the diverticulitis. The only other alternative would have been to excise the major portion of the colon, anastomosing cecum to the terminal pelvic colon, an operation even more formidable than the one the patient did not survive. It would have possessed the advantage, however, of ridding the patient of the complicating diverticulitis.

The most complicated resections in this series of colon cases are constituted by the transverse colon group. Of the 12 patients in the group, 7 had simultaneous resection of the stomach, pancreas, or other viscus. In these 7 patients, the primary lesion was a gastric lesion, a gastrojejunocolic fistula or a carcinoma with invasion of the transverse colon. The case referred to was the only death in the transverse colon group.

The operative mortality for these two periods of study is summarized in Table I. For the earlier period, the operative mortality was 1.6 per cent, for the latter 7.6 per cent, for both periods together, 5 per cent. It is to be noted, however, that there were no unavoidable deaths in the first period, whereas in the latter there were 3 (see Table I). In any series of patients operated upon for visceral malignancy, this item of unavoidable deaths looms large (35). An element of unusual good fortune attended our efforts in the first series in which there were no deaths from unavoidable causes; in the latter series, half of the deaths (3 out of 6) were unavoidable.

Unavoidable deaths. The unavoidable deaths were due to: (1) heart failure in an obese badly decompensated patient with a large invasive lesion of the rectosigmoid; (2) arterial thrombosis of both renal arteries in a decompensated patient who underwent primary resection for cancer of the pelvic colon; (3) an unexplained sudden death in a diabetic (not insulin shock as far as the record indicates), approximately 48 hours after an easy primary resection for carcinoma of the pelvic colon.

HOSPITAL MORTALITY IN AMPULLARY RECTAL RESECTION

Since the former report, 20 additional patients have been operated upon with a view to preservation of the rectal sphincters; of these, one, a man of 80 years, died during the postoperative period, of coronary thrombosis, a mortality of 5 per cent. Of the 7 operated upon in the initial series, 1 died of pyelonephritis and oliguria through the injudicious administration of sulfathiazole, a mortality of 14.2 per cent. The mortality for both series, 2 deaths in 27 patients, is 7.4 per cent.[1]

ARBITRARY SURGICAL DEFINITION OF DIVISION OF LESIONS OF RECTOSIGMOID AND RECTAL AMPULLA

The arbitrary surgical definition of division of lesions of rectosigmoid and rectal ampulla was discussed in the previous report and the problem was resolved by placing the point of division at 10 centimeters from the anus (Fig. 1). Increased experience shows this to be a satisfactory arbitrary divisional point. In resections of the rectosigmoid and rectal ampulla, I have set myself the task of trying to excise routinely a minimum of 3 centimeters of normal mucosa beyond the most distal palpable margin of the tumor at operation, a task easier of accomplishment in lesions of the rectosigmoid than for cancer of the rectal ampulla. In the excised rectal specimen the pathologist not infrequently indicates that the margin of normal mucosa on the distal side of the tumor is less than 3 centimeters. This difference is due, in part, to retraction and shortening following division; yet these short segments of normal mucosa beyond the rectal lesion on the excised specimen accompanied by an adequate length of normal mucosa on the proximal side of the tumor indicate some of the difficulties that beset the surgeon in meeting satisfactorily the requirement of adequate and complete excision of the lesion by ampullary resection.

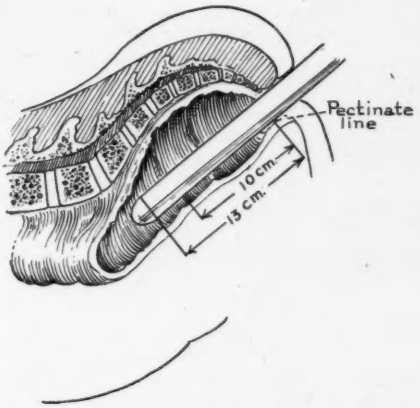


Fig. 1. Arbitrary definition of surgical divisional point distinguishing lesions of the rectosigmoid from the rectum. Lesions whose lower visible or palpable edge is more than 10 centimeters from the pectinate line are classified as rectosigmoidal; those in which the lower palpable or visible edge of the tumor is within 10 centimeters (or less) of the pectinate line are grouped as ampullary rectal lesions (see text). The rectum of the adult is described by anatomists as being ordinarily 13 to 15 centimeters in length. (Reprinted from *Surgery*, 1943, 14: 403.)

As stated in the initial report, rarely is it necessary in lesions whose lower limit is more than 10 centimeters from the anus to mobilize the rectum extensively posteriorly in order to establish intestinal continuity. On the contrary, in lesions below 10 centimeters, regularly, it becomes necessary to mobilize the rectum by division of the middle hemorrhoidal arteries and posterior mobilization to the tip of the coccyx in order to permit of re-establishment of intestinal continuity by suture. Furthermore, there appear to have been no special problems of wound healing attending resection in lesions whose lower proctoscopic limit was more than 10 centimeters from the anus; whereas primary healing occurred only in a minority of the cases in which intestinal union was effected by suture in lesions lying less than 10 centimeters from the anus. This

[1]Eight additional primary ampullary resections for low-lying lesions have been done without mortality. In the 35 patients operated upon to date, therefore, the hospital mortality is 5.7 per cent.

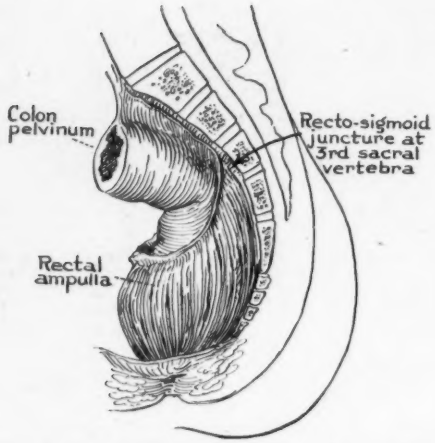


Fig. 2. The rectum and colon pelvinum. The latter, once recognized as a part of the rectum, now is accepted generally as constituting a part of the pelvic colon. As this sketch, redrawn from Corning's *Anatomy* indicates, the rectum is not straight. Mobilization of the deep antero-posterior curve succeeds in elongating the rectum.

report will concern itself particularly with the experiences gained in this clinic with the problem attending resection of low-lying lesions, re-establishment of intestinal continuity, and preservation of sphincteric function.

CAUSES OF POOR WOUND HEALING IN RESECTION OF AMPULLARY RECTAL LESIONS

Granted satisfactory suture, primary healing is the rule in all resections of the colon and the rectosigmoid. The primary difficulty undoubtedly with the low-lying lesions is the vascular factor. That is, mobilization of the rectum to the tip of the coccyx accompanied by division of the middle hemorrhoidal arteries compromises satisfactory vascularization of the lower segment. Furthermore, separation of the rectum from the sacrum leaves a space posteriorly in which fluid will accumulate unless provision is made for drainage.

In resections of the stomach, small intestine, or colon, the surgeon may determine readily by proximity of blood vessels to the segments to be anastomosed as well as by the color whether blood flow will be adequate. The situation in low-lying rectal lesions with repect to resection is not unlike that of total gastrectomy done from within the abdomen. As has been indicated elsewhere, gastric resections up to 95 per cent may be done without special increase of risk above that assumed in the elective 75 per cent resection performed for ulcer (33). When, however, the stomach is excised completely, the mobilized esophagus is deprived of a portion of its blood supply, coming from phrenic and gastric vessels. Whereas a satisfactory suture can be made readily in total gastrectomy, unless the esophagojejunal anastomosis is covered in the manner described by me in 1937 (31) and again by Graham in 1940 (14), fistula formation late in convalescence with development of a subphrenic abscess is not unusual.

In ampullary resection, there is no opportunity to cover the suture line posteriorly. And anteriorly, it is not an easy matter; this item will be referred to again with reference to rectovaginal fistula. As far as I can know or ascertain by rectal examination during convalescence after ampullary rectal resection, in those instances in which a defect occurred in the suture line, the fistula usually was on the posterior rectal wall.

CHOICE OF PROCEDURE IN AMPULLARY RECTAL RESECTION

In the initial report 3 methods of re-establishing intestinal continuity were described: (1) the Hochenegg "pull-through" method with Whitehead excision of the mucosa in the remaining distal segment; (2) the Hochenegg "pull-through" method leaving the rectal mucosa in the distal segment; (3) anastomosis of the proximal and distal segments through a proctoscope.

In the present series, all of these three methods have been employed. I have come to feel, however, that the best method of re-establishing intestinal union in ampullary rectal resection is by the direct suture method made from within the abdomen by the method depicted in Figure 7. Thirteen of the 20 patients in this series were operated upon by the direct suture method. Strange as it may seem, after mobilization of the rectum, anastomosis may be effected by employment of straight clamps and a single row of fine silk Lembert sutures as close as 5 centimeters from the anus. Obviously, it is not an easy anastomosis, but

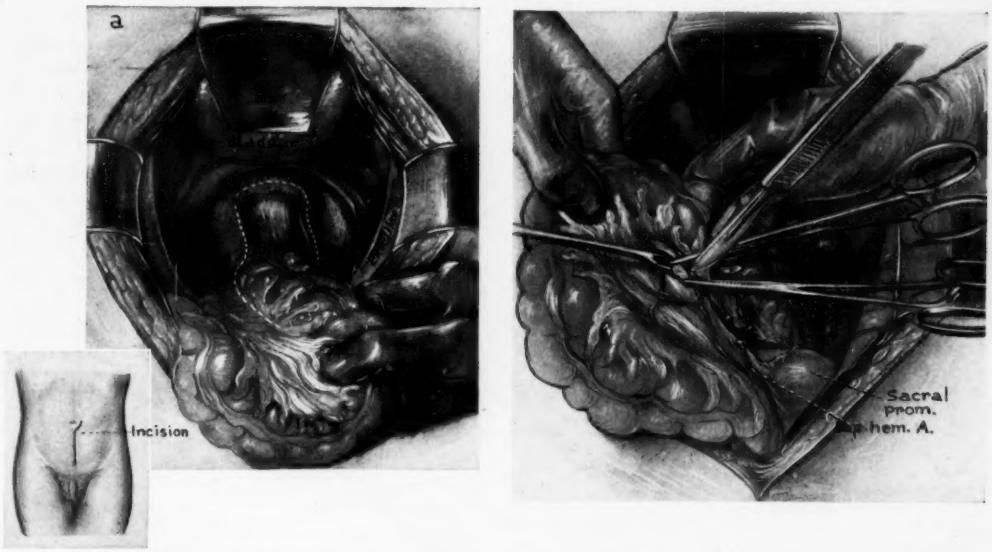


Fig. 3. The technique of ampullary rectal resection: a, left, delineation of peritoneal flaps; b, right, division of the superior hemorrhoidal artery at the sacral promontory together with division of the pelvic mesocolon.

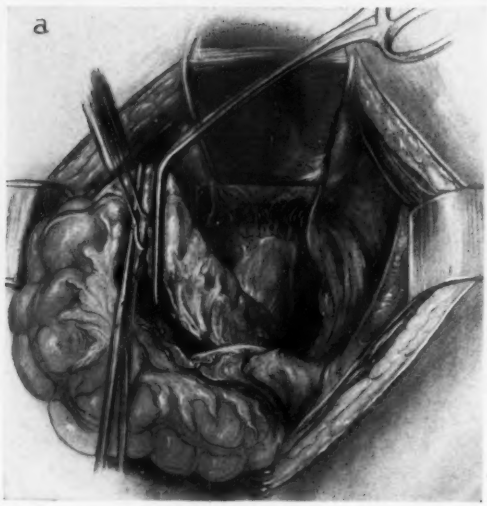
an advantage of this method over anastomosis through the proctoscope is that it may be made as a closed anastomosis. It possesses the advantage over the "pull-through" method that the proximal segment need not be so long; in other words, the suture method does not risk necrosis of the proximal segment or retraction as does the Hochenegg "pull-through" method.

The rectum, when empty, is not straight as its name implies (Fig. 2). There is a deep posterior curve and at least two lateral curves. Not uncommonly, therefore, when the rectum is mobilized fully, the clamp may be applied at the conventional 3 centimeters beyond the lesion permitting resection and anastomosis to be carried out at approximately the same level as the distance which initially separated the anus and the lower limit of the lesion as determined by palpation and proctoscopic examination.

The patients upon whom ampullary rectal resection has been done have been wholly unselected. That is, the operation has been done on every patient with carcinoma of the rectal ampulla in whom it was technically feasible to do it. Obviously, in several instances the operation was undertaken as a palliative procedure; in some of these, as the experience reported herein will indicate, ampullary resection is not a good operation in that in large circumferential lesions exhibiting local invasion and fixation of the tumor ampullary resection is followed frequently by local recurrence.

TECHNIQUE OF PRIMARY RECTAL AMPULLARY RESECTION

The operation is carried out with the patient in steep Trendelenburg position. Miss Daisy Stilwell, medical artist, has prepared the accompanying lucid drawings of the operative procedure (Figs. 2 to 8) from sketches made after looking over my shoulder at two such operations. They illustrate the technique of the operation far better than I can describe it. The details of the operative procedure up to point of applying a clamp to the distal segment are identical with those of the abdominoperineal operation and consist of the following: (1) delineation of peritoneal flaps lateral to the colon; (2) isolation, division, and ligature of superior hemorrhoidal vessels at the sacral promontory (Fig. 3b); (3) division of the



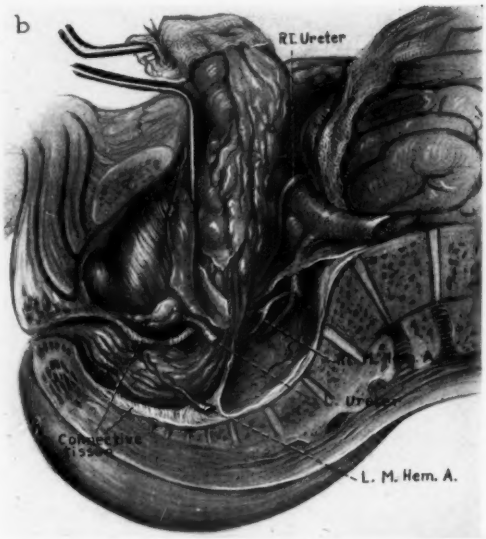


Fig. 4. a, left, Division of the bowel with cautery between two large clamps. A right-angled clamp is placed on the lower segment. b, right, Lower segment of pelvic colon pulled anteriorly over bladder.

colon and pelvic mesocolon (Fig. 4a); (4) mobilization of the rectum to insure excision of 3 centimeters of rectal mucosa beyond the lesion (Fig. 5a, b) and application of the clamp on the distal segment (Fig. 6a); (5) preparation of the proximal segment for the anastomosis (Fig. 6d, e); (6) anastomosis with a single row of fine silk Lembert sutures (Fig. 7); (7) through a short vertical perineal incision made directly in front of the coccyx, the drawing down from the presacral space of a Penrose drain (Fig. 8a, b); (8) placement of a No. 22 rectal tube through the anastomosis; (9) extraperitonealization of the anastomosis and closure of the pelvic floor (Fig. 8c, d), with suture of the lower portion of the peritoneal flaps beneath the colon, and suture of the lateral margins of the colon to the peritoneum again, thus effecting double closure of the pelvic floor. Great pains are taken to make an effective closure of the pelvic floor. The peritoneum is mobilized adequately to obviate tension, and interrupted silk sutures insure firm union.

Cyclopropane supplemented by periodic small intravenous injections of curare has been the usual anesthetic agent. A moderately long, vertical midline subumbilical, or a paramedian rectus, incision is employed.[1] The wound is closed with interrupted sutures of fine silk.

In the earlier cases, in which the Hochenegg "pull-through" operation combined with the Whitehead procedure was employed of mobilizing the normal rectal mucosa beyond the lesion through the anus, it became necessary to operate alternately from below and above. In order to facilitate that procedure the patient was draped on the table with the legs flexed somewhat. This position created a rather awkward situation, particularly for a right-handed first assistant, who then found it necessary in the abdominal part of the operation to reach across the partially flexed right thigh of the patient with his right hand. Mr. John A. Phelan of the scientific apparatus shop in the university then built for me a wall and ceiling windlass which permitted the legs to be flexed or let down at will. Dropping the footboard of the operating table permitted access to the perineum from below. However, the

[1]During the past few months I have employed a vertical midline incision in the lower part of the abdomen; when the posterior rectus sheath is encountered, the incision is directed obliquely to the left transecting the muscles of the abdominal wall. This incision can be closed without tension and promises to afford protection against hernial defects in the wound.

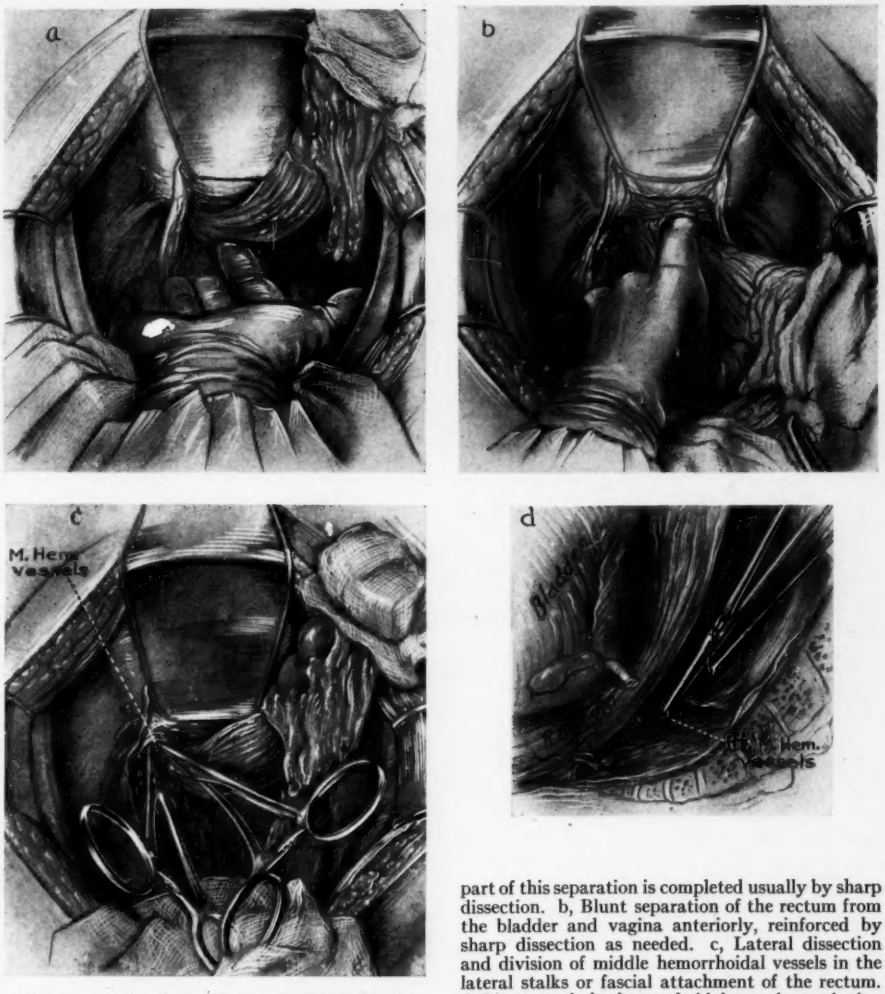


Fig. 5. a, Posterior blunt separation of rectum from parietal pelvic fascia in front of sacrum. Lower part of this separation is completed usually by sharp dissection. b, Blunt separation of the rectum from the bladder and vagina anteriorly, reinforced by sharp dissection as needed. c, Lateral dissection and division of middle hemorrhoidal vessels in the lateral stalks or fascial attachment of the rectum. d, Ligature of the hemorrhoidal vessels employing the "inverter" to carry the ligature down.

abdominal suture method of ampullary resection described herein has made use of the windlass less important.

THE QUESTION OF COLOSTOMY

In colon resections. In this clinic, antecedent or complemental colostomy has been reserved, with few exceptions, for the patient with acute obstruction of the colon. Many patients with mild symptoms of colonic obstruction have been treated by an indwelling tube and large doses of mineral oil permitting resection and primary anastomosis. My associate, Dr. Clarence Dennis (7), has called attention to the hazard of bringing about obstruction by the administration of a barium enema to patients presenting threatening signs of obstruction. In this clinic, routine practice for some time in lesions throughout the entire colon, including the rectosigmoid, has been to perform resec-

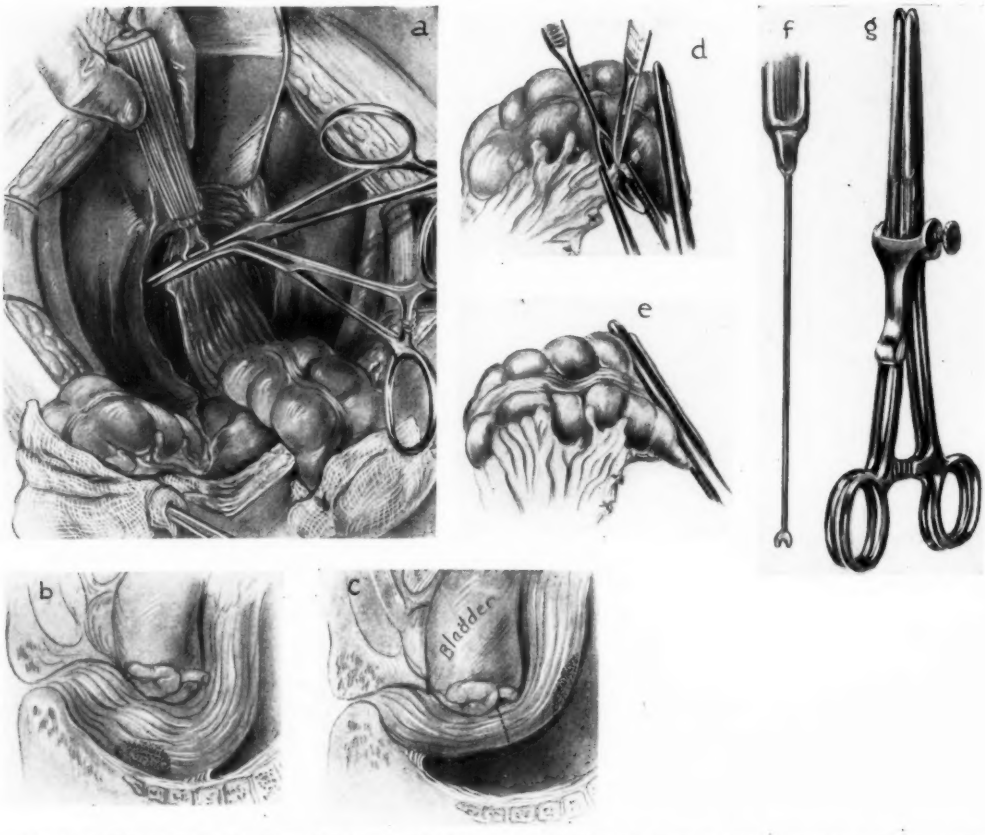


Fig. 6. a, The anastomosis clamp has been applied to the distal segment transverse to its axis and a right-angled clamp is applied proximally, the rectum being cut between with the cautery. b, Situation before rectum is freed up adequately posteriorly. c, After freeing the rectum by sharp dissection posteriorly, the proposed site of section of the rectum is indicated. d, Preparation of the upper segment of the proximal pelvic (sigmoid) colon for the anastomosis; all fatty epiploic appendages are removed. e, Application of the anastomosis clamp at an oblique angle, the width of bowel engaged in the clamp equalling the measured width in centimeters of the rectal segment. f, Suture "inverter"; its use for this purpose is indicated in Figure 7d; its use in carrying ligatures down to the deep lying vessels is shown in Figure 5d. g, The anastomosis clamps.

tion and primary anastomosis without antecedent or complemental colostomy.[1] The regularity with which primary union takes place suggests definitely that colostomy is unnecessary.

An indwelling duodenal tube is allowed to remain *in situ* for 4, and occasionally 5, days after operation. Our experience is that the indwelling duodenal tube is superior to the Miller-Abbott tube in the control of postoperative distention. As has been repeatedly pointed out, however, it is important to employ suction during the induction of anesthesia and during the operation as well as in the early postoperative period. In other words, effective use of the indwelling duodenal tube is the best prophylaxis against distention. The superiority of the Miller-Abbott tube in the treatment of acute obstruction of the small intestine or in instances of mild

[1]The presence of feces in the colon, encountered at operation, proximal to a stenosing lesion does not contraindicate performance of primary anastomosis without colostomy. Several such primary resections have been done without subsequent difficulty. Obstruction accompanied by distention, however, demands a preliminary external decompressive vent.

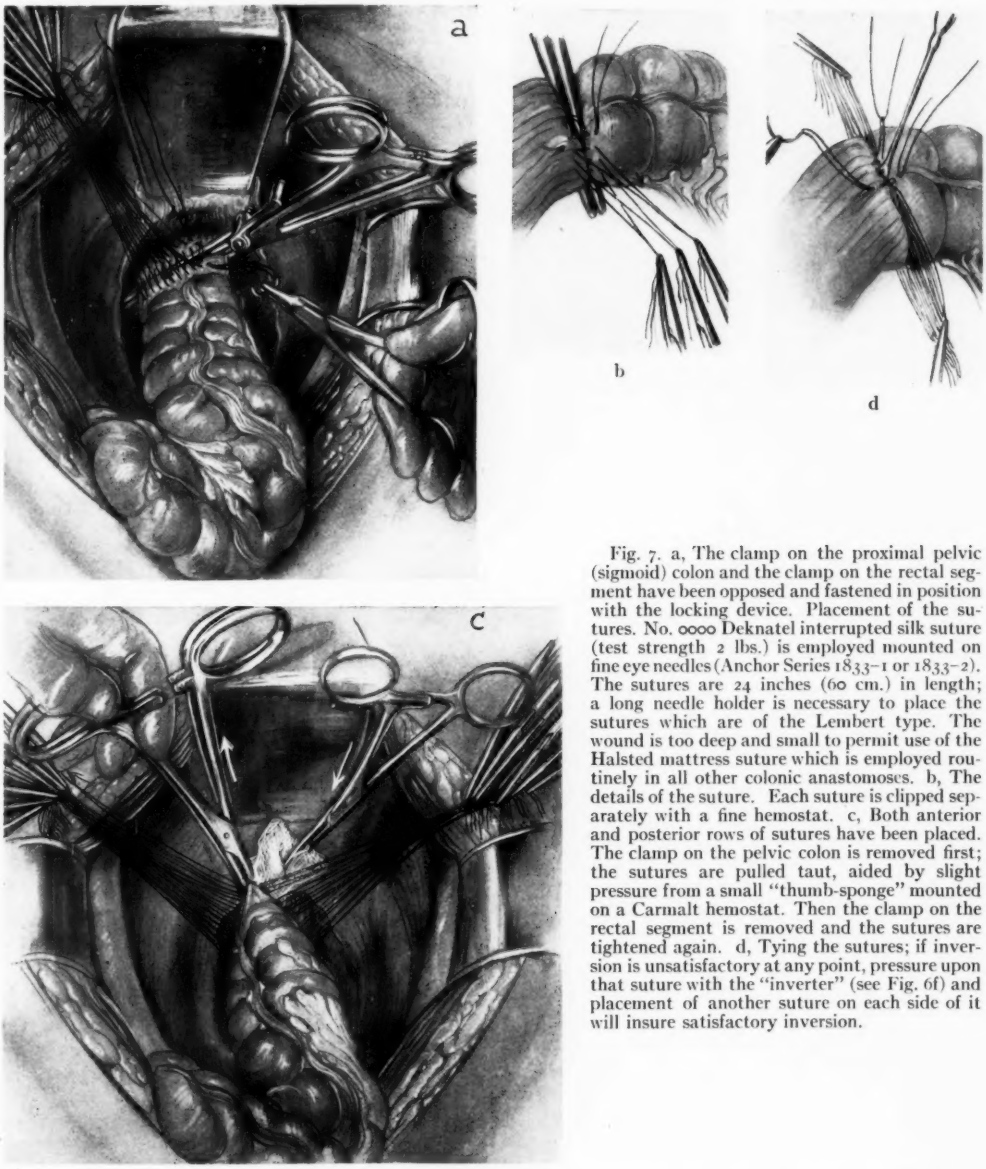


Fig. 7. a, The clamp on the proximal pelvic (sigmoid) colon and the clamp on the rectal segment have been opposed and fastened in position with the locking device. Placement of the sutures. No. 0000 Deknatel interrupted silk suture (test strength 2 lbs.) is employed mounted on fine eye needles (Anchor Series 1833–1 or 1833–2). The sutures are 24 inches (60 cm.) in length; a long needle holder is necessary to place the sutures which are of the Lembert type. The wound is too deep and small to permit use of the Halsted mattress suture which is employed routinely in all other colonic anastomoses. b, The details of the suture. Each suture is clipped separately with a fine hemostat. c, Both anterior and posterior rows of sutures have been placed. The clamp on the pelvic colon is removed first; the sutures are pulled taut, aided by slight pressure from a small "thumb-sponge" mounted on a Carmalt hemostat. Then the clamp on the rectal segment is removed and the sutures are tightened again. d, Tying the sutures; if inversion is unsatisfactory at any point, pressure upon that suture with the "inverter" (see Fig. 6f) and placement of another suture on each side of it will insure satisfactory inversion.

colonic obstruction not demanding early operation is admitted freely.

In ampullary rectal resection, however, employment of complemental colostomy probably will be needed in unobstructed cases more frequently than in primary resection of the colon and rectosigmoid. In this series of cases, particularly in those operated upon after the Hochenegg "pull-through" plan, supplementary colostomy because of persistent

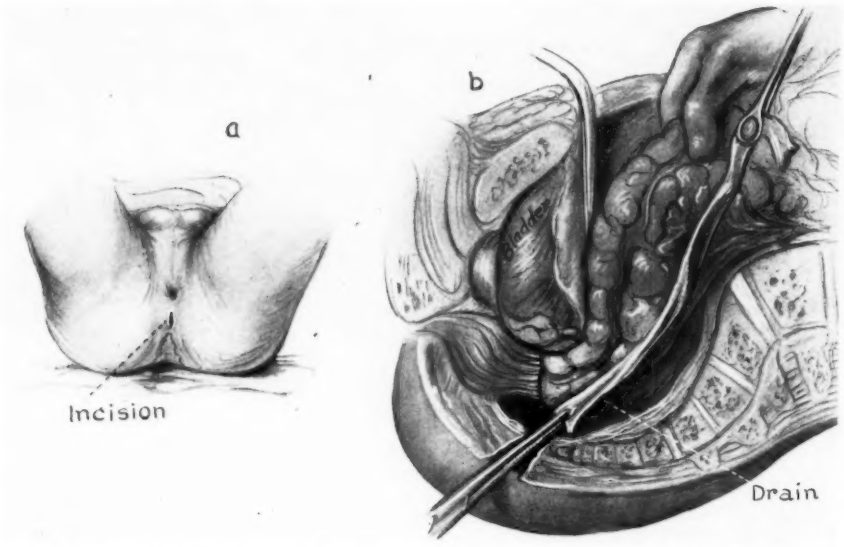


Fig. 8. a, Incision in the perineum just anterior to the coccyx. b, A Penrose drain is drawn through from below.

fever became necessary in several patients—owing to retrorectal infection (Fig. 9). In the main, however, our present plan is to try to effect primary anastomosis by a single row of interrupted silk sutures, elongating the peritoneal cul-de-sac by suturing the peritoneal flaps beneath the colon and draining the residual presacral space through a small incision in front of the coccyx (Fig. 10). Whereas, as has been indicated, a temporary fistula occurred in the larger number of these cases, primary healing without evidence of fistula took place in 4 of 13 patients operated upon by the primary intra-abdominal suture method. In 2 of the 13 patients in this group, a supplemental colostomy was made because of the occurrence of a rectovaginal fistula. Slight elevation of temperature ordinarily heralds the occurrence of a leak in the suture line. Often there is no systemic reaction. Some fecal material usually comes away through the drainage vent. The sinus is irrigated two or three times a day. When the patient becomes afebrile or when it is clear that the leak in the suture line has occasioned no untoward symptoms, the drain is withdrawn. In a few days the external fistulous opening closes spontaneously and the small retrorectal abscess cavity becomes obliterated and the defect in the rectal wall heals. The No. 22 rectal tube threaded past the anastomosis at the time of operation is allowed to remain in place for nearly a week; 3 days after operation it is withdrawn a centimeter to obviate the possibility of the tip of the tube pressing upon the wall of the pelvic colon, causing pressure necrosis. Three days later the tube is withdrawn. In resections of the terminal pelvic colon, in which the rectum is not mobilized posteriorly, no attempt ordinarily is made at operation to pass a rectal tube beyond the anastomosis, for too often easy entry of the tip of the tube into the pelvic colon is prevented by Houston's valves.

SULFONAMIDES UNNECESSARY

As was indicated in the earlier report, the only preoperative preparation of the colon and rectum employed in this clinic is the preoperative administration of enemas preceded by the liberal oral administration of mineral oil. It is an empty bowel that is desired. It has not been our practice to employ succinyl sulfathiazole in colonic or rectal surgery. Moreover, the local implantation of small

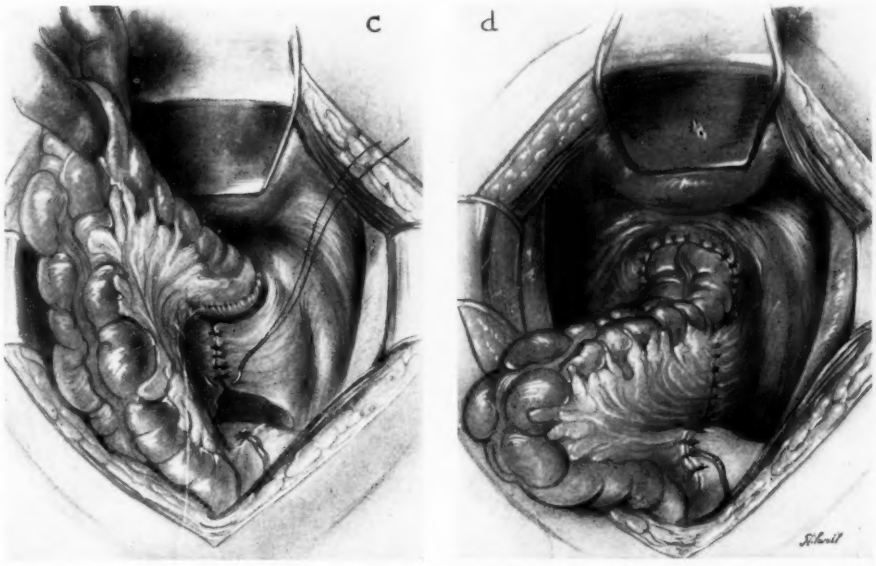


Fig. 8. c, left, The peritoneal flaps are sutured together beneath the pelvic (sigmoid) colon, deepening the peritoneal cul-de-sac. d, right, The closure of the pelvic peritoneum is completed by suturing the lateral peritoneal flaps to the edges of the bowel wall, thus effecting a double closure of the peritoneal floor at the site of emergence of the pelvic colon. At the same time the anastomosis is extraperitonealized.

amounts of sulfathiazole referred to in the earlier report has been abandoned. In those instances, in which a urethral catheter is employed, small daily doses of sulfadiazine are given in the early postoperative period to thwart urinary tract infection.

DIETARY MANAGEMENT

All patients are fed a high protein and carbohydrate and low fat diet for a few days prior to operation. In patients who have lost considerable weight, the preoperative dietary preparation must be long enough to permit the lipotropic action of such a diet to rid the liver of its excess fat—for patients with fatty liver stand operation poorly. The details of this management have been described elsewhere (29, 30, 33).

THE OCCURRENCE OF RECTOVAGINAL FISTULA

We have learned that drainage through the vagina is inadvisable in any of the methods of ampullary rectal resection. If perirectal suppuration occurs, a persistent rectovaginal fistula may follow. Moreover, a spontaneous rectovaginal fistula has been observed twice without drainage of the vagina. My colleague, Dr. John L. McKelvey (17), professor of obstetrics and gynecology (1944), informs me this occurrence is probably owing to the dependence of the posterior vaginal wall on the blood flow from the middle hemorrhoidal arteries which are divided regularly in the operation of rectal resection, an expression which finds confirmation in the anatomical observations of Quenu (24, 1893). The distribution of the branches of the middle hemorrhoidal arteries is principally upon the anterior wall of the rectum above the levatores, while the branches of the inferior hemorrhoidal arteries are dispersed largely upon the posterior wall below the levatores (Cunningham). There is no marginal artery of the rectum as in the colon. As the three hemorrhoidal arteries reach the rectal wall, they break up into branches which are distributed over and through the rectal wall.

Lately, in adherent lesions in the female, I have excised the uterus and the upper portion of the vagina coincident to re-establishing

Fig. 9. Mucosa of the pelvic colon projecting through the anal canal in the Hochenegg "pull-through" operation (Table II, Case 7). Survival of this segment is not always predictable (see text). This cuff of protruding bowel is cut off late in convalescence, flush with the sphincter.

intestinal union in ampullary resection, thus insuring better removal of the tumor and avoiding simultaneously the hazard of a rectovaginal fistula. In a recent case after such a procedure, primary union occurred, the suture line being 5 centimeters from the anus (Fig. 10).

ARTERIES OF THE RECTUM

Steward and Rankin (1933) give a good account of our available knowledge on the blood supply of the lower colon and rectum. Quenu (1893) and Drummond (1914) have both stressed the inconstancy of well developed anastomosing vessels between the middle hemorrhoidal and the superior hemorrhoidal arteries above the levatores, on the one hand, and between branches of the middle hemorrhoidal and branches coming from the inferior hemorrhoidal beneath the levatores on the other. The latter communication is even more feeble than the former.

Fig. 10. Drainage site proximal to coccyx in ampullary rectal resection by suture. Healing occurred without a temporary fistula in this instance (Table II, Case 24).

In one of 13 dissections, Quenu failed to demonstrate any communication between branches of the superior and middle hemorrhoidal arteries on the rectal wall; in the remaining 12, the communication was unilateral and not with inosculating branches on both sides of the rectum as one might expect. Drummond believes the middle hemorrhoidal artery to be an inconstant vessel inasmuch as he was able to demonstrate its presence employing the x-ray injection technique only 3 times in 12 specimens. His skiagrams emphasize the importance of the superior hemorrhoidal artery in vascularizing the rectum.

Quenu states that the middle sacral artery gives off usually three small branches at the level of the last sacral vertebra to the posterior aspect of the rectum. Pope and Buie (1929) describe a retrorectal plexus to which small branches of the middle sacral artery supply inconstant components.

The superior hemorrhoidal is the chief artery of the rectum and inasmuch as the paired middle and inferior hemorrhoidal arteries are variable and inconstant, it is understandable that, attending division of the superior and middle hemorrhoidal arteries in ampullary rectal resection, difficulty with wound healing and temporary rectal fistula are not uncommon. It has been pointed out

previously that Sudeck's (1907) critical point has no importance in excision of the colon pelvinum and the upper rectum. Probably only in the "pull-through" operation is Sudeck's critical point really important. In that procedure, as has been pointed out, the proximal pelvic colon must be several centimeters longer than is necessary in ampullary resection by the primary suture method. Whereas the bowel is usually long enough, the primary difficulty with the "pull-through" maneuver relates to the shortness of the vessels in the mesentery, despite all efforts at lengthening them. If the sigmoid ima artery is cut the marginal vessels along the mesenteric border of the colon may be inadequate to vascularize it. In consequence, necrosis and retraction of the segment drawn down through the anus may occur. As in ampullary rectal resection, the superior hemorrhoidal artery is divided also in rectosigmoid resections; however, in the latter operation, the communications between the terminal branches of the superior hemorrhoidal and the middle hemorrhoidal on the rectal wall are not disturbed and difficulty with wound healing does not occur.

AMPULLARY RESECTION FOR ULCERATIVE COLITIS

Three of the 27 patients in whom ampullary resection was done had ulcerative colitis. The remaining 24 had cancer of the rectum. In 1 of the 3 patients with ulcerative colitis, there was a localized lesion extending from 9 to 14 centimeters from the rectum, permitting ampullary resection with anastomosis to the proximal portion of the pelvic colon; in another, the whole colon was involved and a rectal stricture was present 10 centimeters from the anus (Fig. 11, specimen 8); in this instance the end of the ileum was sutured to the terminal rectum. In the third patient, referred to in the initial report, the whole colon and rectum were involved, necessitating complete excision of both, the problem being resolved by pulling the ileum down through the external sphincter after the Hochenegg "pull-through" method, accompanied by Whitehead excision of the rectal mucosa from the distal segment. Primary healing did not occur in any of these 3 patients.[1] Rectal function has been quite satisfactory in the first 2 patients. As was indicated in the first report, in the instance of the patient with complete colectomy and proctectomy, recourse had to be had to a secondary ileostomy. This patient can retain 4 ounces of water administered by a rectal tube for a period of 8 minutes without too great difficulty, and the prospect of again re-establishing intestinal continuity appears not unlikely. If the Whitehead excision of mucosa from the distal segment had not been employed, the prospect of satisfactory rectal function in this patient undoubtedly would be even better.

Sphincteric function. Ampullary resection was undertaken in 27 patients; of these, 2 died in hospital. In 2 of the remaining 25 patients surviving ampullary resection, in whom a supplemental colostomy became necessary, no opportunity was afforded to test sphincteric function; one of these, Mrs. M. R., Univ-Hosp. No. 743136, aged 68 years, had hepatic metastases and a growth adherent to the cervix and posterior vaginal wall. A local recurrence precluded secondary closure of the colostomy and excision of the two hepatic nodules. Additional experience has suggested the advantage of excising the uterus and the upper portion of the vagina in such patients. The other patient, Mrs. P. R., Univ. Hosp. No. 746841, aged 68 years, developed evidence of a pyelonephritis after leaving hospital and died 2 months after operation of a pulmonary embolus. The predisposition of patients having colostomy to development of urinary tract infection appears to be well established.

Of the remaining patients, sphincteric function appears to be satisfactory in the majority. All the patients in the group have been followed and observed from time to time. In order that patients might not be persuaded to give more favorable replies at the time of examination than the situation warrants, the following inquiry was sent to all patients having had ampullary resection:

1. Is the rectal control satisfactory?

2. Are there periods when the control is not satisfactory?

[1]An additional patient with ulcerative colitis has recently undergone colectomy and partial proctectomy with end-to-end union between ileum and rectum with primary union.

TABLE II.—RESULTS IN 27 PATIENTS UNDERGOING AMPULLARY RECTAL RESECTION*

Name and hospital number	Sex Age	Distance of lesion from anus—cm.	Character of lesion	Supplemental colostomy	Complications	Length of hospital stay after operation—days	Sphincteric function	Present status, remarks
I. Hochenegg "Pull-Through" with Whitehead Excision of Mucosa of Lower Segment								
1. Mrs.B.A. 721881	F 40	10	B Ulcerative lesion, also rectal polyp Weight 237 gm. Length 26 cm.	None	Temporary stricture, thrombophlebitis	37	Very good	Well
2. Mr.F.C. 721978	M 79	8	C Ulcerative lesion Weight 200 gm. Length 39 cm.	None	Temporary stricture	30	Good	Well
3. Mr.R.L. 722751	M 63	4	C Sessile growth Weight 195 gm. Length 23 cm.	None	Temporary stricture	17	Good	Well
4. Mr.C.E. 684951	M 16	0	Ulcerative colitis; colectomy, proctectomy	Ileostomy	Posterior space infection	84	Holds 4 oz. 8 min. Anatomic result good	Well. Still has ileostomy
5. Mr.N.F. 723502	M	4	C Ulcerative lesion Weight 500 gm. Length 25 cm.	None	Pyelonephritis, oliguria from sulfonamides		No observation	Died 12th day postoperative
6. Mr.C.W. 729462	M 59	6	C Sessile growth adherent to base of bladder. Weight 110 gm. Length 12 cm.	None	Temporary stricture	20	Good	Died of recurrence 15 months after operation
7. Mrs.E.L. 737846	F 69	5	B Ulcerative lesion Weight 115 gm. Length 13 cm.	Yes	Posterior space infection	28	Fair. Wears incontinence pad. Anatomic result good	Well. Colostomy closed
8. Mr.P.M. 740083	M 61	10	C Constricting circumferential lesion. Large single metastasis to liver. Weight 310 gm. Length 19 cm.	Preliminary for obstruction	Diabetes, toxic goiter, perirectal abscess	28	Fair	Well. Excision of hepatic metastases. Colostomy closed
II. Hochenegg "Pull-Through" Leaving Mucosa in Distal Segment								
9. Mrs.A.L. 722707	F 66	10	C Annular, ulcerating gelatinous carcinoma, lesion 7 x 9 cm. Weight 410 gm. Length 22 cm.	None	None	28	Good	Recurrence of lesion, subsequent abdominoperineal operation with recurrence
10. Mr.H.S. 683484	M 69	9	C Broad circumferential lesion. Weight 205 gm. Length 13 cm.	Yes	Obesity diabetes	24	Fair. Wears incontinence pad	Well. Closure of colostomy. Mild senile psychosis evident even before operation
III. Suture Anastomosis through Proctoscope								
11. Mrs.F.V. 730072	F 36	6	B Ulcerating circumferential lesion Weight 190 gm. Length 17 cm.	None	None	18	Excellent	Well
12. Mrs.J.O. 734753	F 64	6	C Ulcerative lesion. Weight 200 gm. Length 25 cm.	Yes	Posterior space infection. Drainage through vagina. Rectovaginal fistula	42	Good	Well. Closure of colostomy. Slight, persistent drainage through vagina

*Four types of operation; Duke's classpathological ification indicating weight and length of excised segment.

TABLE II.—RESULTS IN 27 PATIENTS UNDERGOING AMPULLARY RECTAL RESECTION—Continued

Name and hospital number	Sex Age	Distance of lesion from anus—cm.	Character of lesion	Supplemental colostomy	Complications	Length of hospital stay after operation—days	Sphincteric function	Present status, remarks
III. Suture Anastomosis through Proctoscope—Continued								
13. Mr.I.F. 737235	M 51	9	C Large circumferential ulcerating lesion. Metastases to liver. Weight 195 gm. Length 9 cm.	Yes	Obesity, posterior space infection	29	Good	Closure of colostomy. Excision of hepatic metastases. Death from recurrence 10 months postoperative
IV. Primary Closed Anastomosis (Suture from Above)								
14. Mrs.E.E. 734632	F 66	8	B Ulcerating polypoid lesion Weight 182 gm. Length 25 cm.	None	None	10	Excellent	Well
15. Mrs.R.V. 740748	F 42	8	B Ulcerated lesion. Weight 145 gm. Length 11 cm.	Yes	Posterior space infection	47	Excellent. Colostomy closed	Well
16. Mr.T.D. 741423	M 45	10	B Ulcerating sessile lesion. Weight 70 gm. Length 9 cm.	None	Postoperative thrombophlebitis	24	Excellent	Well
17. Mrs.M.R. 743136	F 68	6	C Broad circumferential ulcerated sessile growth. Weight 240 gm. Length 27 cm.	Yes	Posterior space infection. Rectovaginal fistula	28	No observation	Died 6 mo. after operation. Hepatic metastases not excised
18. Miss M.K. 715874	F 19	10	Ulcerative colitis. Removal of entire colon and upper rectum	Ileostomy	Posterior space infection	62	Excellent	Well. Ileostomy closed
19. Mr.I.C. 744016	M 80	8	B Ulcerative circumferential lesion Weight 165 gm. Length 20 cm.	None	None		No observation	Died 5th postoperative day, coronary thrombosis
20. Mrs.C.L. 744632	F 65	6	C Sessile ulcerating lesion; also polyp. Weight 190 gm. Length 19 cm.	None	Obesity, postoperative infection. Rectovaginal fistula	62	Good save for rectovaginal fistula	Well. Recent unsuccessful repair of rectovaginal fistula
21. Mr.O.C. 744375	M 78	6	C Large circumferential adherent ulcerative lesion. Weight 280 gm. Length 25 cm.	None	Posterior space infection	17	Good until recurrence	Local recurrence which responded to radium
22. Mr.J.C. 744810	M 53	10	B Broad circumferential ulcerating lesion. Lower segment, weight 185 gm. length 25 cm. Upper segment weight 295 gm. length 25 cm.	None	Posterior	25	Excellent	Well. Had catarrhal jaundice since hospital stay
23. Mrs.P.R. 746841	F 68	6	C Large annular ulcerative lesion, invasion of uterus and vagina. Weight 330 gm. Length 12 cm.	Complemental colostomy because of contamination at operation. (Open anastomosis)	Pyelonephritis, posterior space infection	23	No observation	Colostomy not closed. Died of pulmonary embolism somewhat more than 1 mo. after dismissal

TABLE II.—RESULTS IN 27 PATIENTS UNDERGOING AMPULLARY RECTAL RESECTION—Continued

Name and hospital number	Sex Age	Distance of lesion from anus—cm.	Character of lesion	Supplemental colostomy	Complications	Length of hospital stay after operation—days	Sphincteric function	Present status, remarks
IV. Primary Closed Anastomosis (Suture from Above)—Continued								
24. Mrs.E.J. 747377	F 46	9	Primary gelatinous carcinoma of ovary invading cervix, vagina and rectum. Previous subtotal hysterectomy. Weight 465 gm. Length 24 cm.	None	None	15	Excellent	Well
25. Mrs.M.C. 746966	F 21	9	Ulcerative colitis. Weight 140 gm. Length 20 cm.	None	Posterior space infection	28	Good	Well
26. Mrs.E.S. 747880	F 59	10	C Very large adherent and fixed circumferential polypoid lesion—independent polyps. Hepatic metastases. Weight 755 gm. Length 28 cm.	None	Obesity, diabetes	20	Excellent	Satisfactory. Hepatic metastases not excised
27. Mr.J.O. 747552	M 73	8	B Large polypoid circumferential lesion. Weight 415 gm. Length 28 cm.	None	Posterior space infection. Severe senile psychosis	27	Poor. Anatomic result good	Committed to mental institution for psychosis

3. Do you find it necessary to wear a diaper or take other precautions against soiling?

4. Can you control gas?

5. Has your activity been limited in any way by the operation on the rectum?

The replies to this questionnaire tallied quite closely with our own evaluation and the results appear in Table II. The patients with excellent or normal sphincteric function all had ampullary rectal resection by the suture method. The same set of questions was submitted to the patients who had undergone resection for carcinoma of the rectosigmoid. Uniformly, the sphincteric function of that group seemed to be normal.

The preservation of normal or nearly normal sphincteric function in the majority of the patients undergoing ampullary rectal resection has been very gratifying. In patients in whom a rectal fistula, developing from a leak in the suture line, was slow in closing and healed with a persistent defect in the rectal wall, rectal continence has been impaired. Moreover, a rectovaginal fistula has marred an otherwise satisfactory continence in 2 patients. Equally, or even more important than local causes in disturbing sphincteric function have been mental changes owing to senility. Patients who have undergone ampullary resection must be more alert to the necessity of evacuating the lower bowel than the patient with an intact rectum.

Babcock (1932) removes the sphincters and establishes a perineal anus in doing the radical operation for rectal cancer (2). Babcock and Bacon (1942) assert (3) that the sphincterless perineal colostomy is to be preferred to the abdominal colostomy. Whereas for sentimental reasons, the perineum may appear to be a more desirable location for an artificial anus, it would seem better to have such a colostomy opening where it may come more directly under the watchful eye of its owner.

Preservation of sex function in males. Loss of sex function or impotence in males after the abdominoperineal operation is well known. Apparently in patients undergoing ampullary rectal resection as in patients having had excision of the rectosigmoid, there appears to be little or no impairment of this function.

LOCAL RECURRENCE

Of the 27 patients in whom ampullary resection was done, in 3, the operation was under-

taken for ulcerative colitis, the remaining 24 had cancer of the rectum. Two of these failed to survive operation. Of the 22 patients surviving ampullary resection for rectal cancer, 5 had evinced evidence of local recurrence. In 4 of these, ampullary resection was undertaken as a palliative procedure. Yet, even in these patients the abdominoperineal operation would have given better assurance against local recurrence. This matter of local recurrence in large fixed lesions has been the most disappointing experience in this effort directed at preserving sphincteric function in ampullary resection. Two of these 5 patients had hepatic metastases at the time of operation. One of these, Mrs. M.R., Univ. Hosp. No. 743136, was mentioned under the discussion of the complication of rectovaginal fistula. In one patient, the large fixed resected lesion proved to be a gelatinous carcinoma. An abdominoperineal operation was done subsequently but the lesion has recurred again. Miles (1931) states (19) that such gelatinous carcinomas as well as melanotic lesions are not curable by any known means. Broders, Buie and Laird (1940) and Norbury (1941) while allowing that colloid cancers are usually highly malignant, are not as pessimistic over them as Miles. Dukes (1940) places all colloid or mucoid cancers in a separate and distinct group (11). All 5 of the patients in whom recurrence developed in this series had large fixed low-lying lesions which had penetrated the fascia propria of the rectum, presenting at the same time metastatic lymph nodes in the pelvic mesocolon. The first ampullary resections reported herein were done in 1942; in other words, even the first patients in the group were done less than 3 years ago. The elapse of additional years obviously will be required before one can evaluate the factor of long term survival.

Gilchrist and David (1938) studying cleared specimens excised in the abdomino-perineal operation for rectal carcinoma found metastatic lymph nodes in 68 per cent of the cases; Coller and his associates (1940) in 64 per cent and Gabriel and his associates (1935) observed lymph node metastases in 62 per cent of dissected specimens. Gilchrist and David concluded that large tumors may have no lymph node metastases whereas small tumors may occasionally present evidence of extensive lymphatic spread. They point out further that when there is gross involvement of high lymph nodes, there may be retrograde metastases to lymph nodes lying below the tumor.

Whereas Coller and his associates (1940) failed to find evidence of lateral lymphatic spread in lesions lying more than 3 centimeters above the anorectal line, I am convinced from the experience with low-lying fixed lesions that an operation which does not excise the levator muscles in juxtaposition to the bowel invites local recurrence. In the 5 instances reported herein, in which local recurrence followed ampullary resection, the local invasive qualities of the tumor may have been responsible. Yet, I believe it would be safer to suggest that ampullary resection in such instances can be indicted on the score of failing to remove the lateral zone of lymphatic spread as well as in its failure to deal adequately with the item of local invasion. Miles (1931) states that the levator ani muscles are especially prone to invasion by cancer cells which have gained access to the extramural lymphatic system of the rectum (20).

The primary defect in the perineal operation for rectal cancer apart from the loss of sphincter function is that it fails to deal with the upward zone of spread. The potential defect in ampullary resection for rectal cancer is that, when applied to unsuitable cases, patients with large, low-lying lesions, it fails to deal with the item of lateral lymphatic extension via the fascia overlying the levator muscles; further, it compromises somewhat on the extent of excision of the rectal wall distal to the lesion. From the standpoint of cure of rectal cancer, obviously, the abdominoperineal operation is the best procedure. In how many instances, however, would ampullary resection protect equally as well against recurrence and, at the same time, save the patient's sphincter? Many surgeons latterly are coming to the point of view in the management of cancer of the esophagus, if esophagogastric or esophagojejunal anastomosis can not be effected, that the patient should not be subjected to the alternative procedure of the Torek operation with establishment of an external

fistula. An exteriorized esophagus is a severe handicap contrasted with the lesser troubles of a colostomy. Nevertheless, it is perhaps not out of place to point out that surgeons can make but a poor imitation of the rectal sphincters which nature bountifully bestowed on us; neither can one be bought at any price in any market, open or dark.

A number of studies indicate that approximately 50 per cent of unselected patients subjected to the abdominoperineal operation survive 5 years without recurrence: Jones (15, 1929) 47.8 per cent; Pemberton and Dixon (22—1934) 35.8 per cent (includes all operations for cancer of the rectum); Abel (1935) 58.5 per cent; Jones, (16—1936) 52.6 per cent for the one stage and 51.3 per cent for the two stage abdominoperineal operation. It is reasonable to infer that the losses by death from recurrence of the malignant growth are sustained largely in the group exhibiting local invasion and lymph node metastases (Dukes' group C). In other words, even the best and most radical operation is inadequate for a large number of such cases. Dixon (1944) informs me that in a series of 100 patients with rectal cancer operated upon more than 5 years previously there were no 5 year survivals among patients whose lesions fell into Dukes' group C. Similarly, in a small series also reported from the Mayo Clinic by Seefeld (1942) there were no 5 year survivals in patients whose lesions were placed in Broders' group IV. Among 191 patients whose excised lesions were classified in Dukes' group C, Broders, Buie and Laird (1940) found only 14.6 per cent of 5 year survivals; and among 18 patients whose lesions were placed in Broders' group IV they observed only 11.1 per cent 5 year survivors. In this connection, Miles (20—1931), the innovator of the abdominoperineal operation said concerning it: "Should it be reserved for advanced cases only, as advocated by some, then the invisible spread will have advanced beyond the confines of the operation field and recurrence will be inevitable" (11). It would be difficult to justify any operation for cancer on the basis of accomplishment in the late case.

In this study, Dukes' (10, 11—1932, 1940) well known scheme of classifying rectal tumors has been employed. It is my impression that Dukes' scheme may not be as useful to the surgeon as it is to the pathologist, for it implies that metastases do not occur unless local invasion has occurred. It would be more in keeping with surgical experience to indicate that any malignant tumor with or without local invasion beyond the confines of the rectum may be accompanied by lymph node metastases, even though this incidence mounts sharply when the primary tumor exhibits definite evidence of local invasion.

HEPATIC METASTASES

The occurrence of hepatic metastases indicates definitely that vascular embolism of tumor cells occurs in malignancy. Coller and his associates (1940) noted evidence of direct local invasion of venous channels in 15 per cent of the rectal specimens studied.

Coincidental partial hepatectomy for direct extension of a malignant growth into the liver at the time of gastric resection for cancer has been described previously (33). A more protracted period of observation of the patients in which that procedure was carried out confirms the validity of the worthwhileness of such a maneuver. Because of the length of survival of many patients undergoing primary resection of the colon for cancer, presenting hepatic metastases at the time of operation, I suggested previously that secondary excision of hepatic metastases reasonably might be undertaken in such cases. It is only within the past year, however, that I have been able to persuade patients to undergo such secondary resections. If protracted followup in such patients should indicate that survival is no greater than in a similar group in which the metastases are left, one might yet learn something of the manner of growth of hepatic metastases. My thesis is that if at the first operation the local lesion and the lymphatic drainage area can be excised satisfactorily, secondary excision of the hepatic metastases 6 to 8 weeks later may cure the lesion. Failure to palpate metastases not near the surface in an organ as thick as the right lobe of the liver is admitted freely.

Hemostasis is not a difficult problem in excision of hepatic tissue. There is so much

fibrous tissue in the liver that bleeding may be controlled readily. The cautery is employed to remove the section of the liver involved. Large vessels are seized with hemostats as they are encountered and the vessels are ligated. In a deep wound, the vessels in the liver substance can be distinguished readily by palpation; that is, the hepatic substance may be readily compressed between thumb and forefinger disrupting the tissue continuity, leaving the vessels intact. Fibrin-foam (Cohn) has been a helpful adjuvant agent in the control of parenchymatous oozing. When the vessels which traverse the defect in the liver are ligated, however, ordinarily the problem of hemostasis is not particularly difficult. The adjacent edges are sutured if possible with a running suture of catgut and the transverse mesocolon or other available omental structure is employed to sew over the defect, with the thought in mind of localizing the inevitable temporary bile fistula. External drainage is therefore always provided and temporary external drainage of bile is usual.

During the past year, three such secondary excisions of metastases have been undertaken. Two of these secondary partial hepatectomies were done for rectal malignancy in which an antecedent ampullary resection was done and one in a patient who developed a local recurrence following an exteriorization operation done elsewhere for a carcinoma of the pelvic colon. Six weeks after simultaneous removal of the colostomy, the local recurrence in the abdominal wall and performance of primary anastomosis, metastases were excised from both lobes of the liver (Fig. 12, specimen C). In one of the rectal cases, the metastasis was large and single, involving the lateral portion of the right lobe of the liver. The gall bladder was freed and deflected to the left. The excised liver tissue weighed 335 grams (Fig. 12, specimens A and B). These two patients continue well. In the other patient, two metastases were present in the right lobe of the liver. This patient also had a large fixed circumferential lesion that was removed with difficulty, the Hochenegg "pull-through" operation being done. Supplemental colostomy became necessary because of fever and perirectal suppuration. A few weeks later the colostomy was closed and the hepatic metastases were excised at the same time. The rectal function was quite satisfactory. A few months later, however, evidence of local recurrence became apparent. This patient died of local recurrence involving both ureters, somewhat more than 10 months after ampullary resection. Two hepatic metastases were again present in the right lobe of the liver at autopsy. Whether these final hepatic metastases were the result of inadequate removal of the initial hepatic metastases, failure to palpate occult subsurface metastases or failure to remove the local lesion completely cannot be determined.

AMPULLARY RESECTION COMBINED WITH REMOVAL OF METASTATIC LYMPH NODES PROXIMAL TO THE PELVIC MESOCOLON

Mention has already been made of 2 instances in which resection of the whole colon and the greater portion of the rectum was made for ulcerative colitis. In a patient, Mr. J. C., Univ. Hosp. No. 744810, aged 53, with carcinoma of the rectal ampulla presenting lymph node involvement proximal to the pelvic mesocolon, following excision of these nodes and the inferior mesenteric artery at its site of origin from the aorta, it became evident that the left colon was not adequately vascularized through the midcolic artery and the marginal branches of the left colic artery. In consequence, it became necessary to mobilize the entire colon up to and including the hepatic flexure (Fig. 11, specimen 7). The left half of the transverse colon was finally anastomosed to the rectum. If the transverse colon had not been so long, it might have been necessary to anastomose the cecum to the rectum. This patient has satisfactory sphincteric function. In the earlier report, it was indicated that the terminal ileum or the cecum had been anastomosed to the terminal pelvic colon in 7 patients without mortality.

INDICATIONS AND CONTRAINDICATIONS TO EMPLOYMENT OF AMPULLARY RESECTION

It is to be admitted freely that this operation cannot compete in all cases of rectal cancer with the abdominoperineal operation. It is immediately apparent that its employment is contraindicated in juxtasphincteric malig-

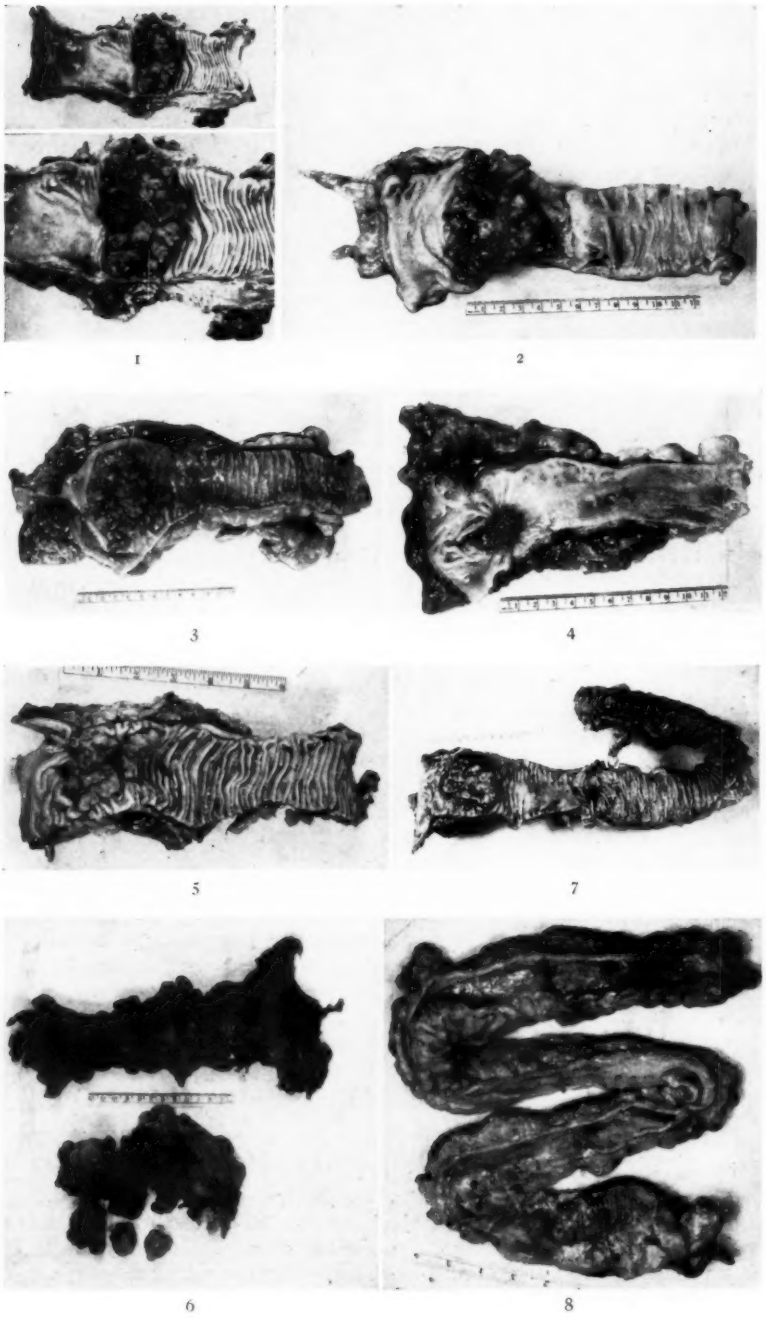


Fig. 11. Representative excised specimens in ampullary rectal resection: 1, Case 1, Table II, length of specimen 26 centimeters; weight 237 grams. There is an additional polyp superiorly just beneath the principal lesion. 2, Case 19, Table II. 3, Case 27, Table II. 4, Case 20, Table II. 5, Case 17, Table II; the invasive character of the lesion is apparent. At operation, the tumor had to be dissected off the cervix and vagina. Simultaneous excision of the upper half of the vagina and the uterus probably would have precluded local recurrence. The patient also had hepatic metastases. 6, Case 24, Table II; the primary lesion here was carcinoma of the ovary with involvement of the rectum. An antecedent subtotal hysterectomy had been done elsewhere 2 years previously. In this procedure, the cervix, upper half of the vagina, and the upper two-thirds of the rectum were removed. Primary healing occurred (see Fig. 10). 7, Case 22, Table II; anastomosis between the rectum and the transverse colon was effected after excision of this lesion. 8, Case 18, Table II; excision of all of colon and upper half of rectum for ulcerative colitis.

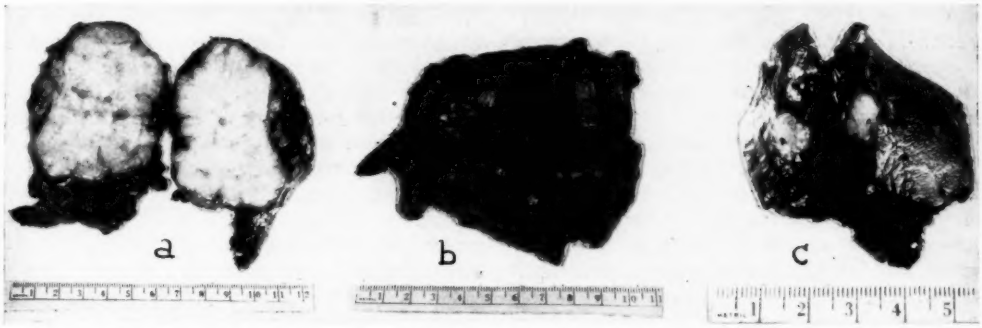


Fig. 12. Secondary excision of hepatic metastases: a and b, Case 8, Table II; there was a large single hepatic metastasis in the right lobe of the liver (w. 335 grams). c, Small metastasis from the right lobe of the liver in a patient with carcinoma of the descending colon. A similar metastasis was removed at the same time from the left lobe of the liver (see text). It is problematic, of course, whether these were the *only* hepatic metastases.

nancies, on the score of inadequate removal of the local lesion; furthermore, in all lesions at the level of the levator muscles, the operation is contraindicated on the score that this procedure does not permit division of the levator muscles and adequate removal of the lateral zones of lymphatic spread.

Hence in all large fixed ampullary lesions in which the tumor has extended beyond the confines of the fascia propria of the rectum and a real opportunity for spread into the lateral lymphatic zone exists, ampullary resection should not be undertaken. In other words, in instances in which there is real hazard of local recurrence, the abdominoperineal operation should be favored over ampullary resection. Apart from these considerations, the operation of ampullary rectal resection described herein would appear to deal as well with the problem of rectal cancer as does the abdominoperineal operation. The avenues for upward lymphatic extension of malignant growth into the pelvic mesocolon can be dealt with equally as well by the operation of ampullary resection as by the abdominoperineal operation.

DISCUSSION

The following are the items which concern both patient and surgeon in this and any other operation for malignancy: (1) operative mortality, (2) possible complications of operation, (3) prospects of ultimate cure, (4) function.

Preservation of sphincteric function is the special consideration which compels interest in ampullary resection. The operation appeals at once to the patient. The thought of a colostomy is ordinarily abhorrent and frequently revolting to a patient. Mere mention of a possibility of saving the sphincters immediately arrests the patient's interest. There are patients who *will not* accept a colostomy. There were a few such patients in this group. Yet, 2 such patients, when evidence of local recurrence developed following ampullary resection for fixed circumferential lesion, willingly accepted colostomy and subsequent efforts directed at extirpating the recurrence. All surgeons have had experience with patients who will not submit to operation if told they have cancer. Obviously, they are unreasonable, but this type of mania sometimes defies being set aside. An operation which must be defended on the thesis that it may be a satisfactory substitute for patients who are more interested in preservation of function than in cure, is obviously not a good operation for cancer.

There are patients for whom a colostomy is a heavy and tragic burden. The majority of reasonable patients, however, learn to deal with the situation and tolerate colostomy without complaint. It is probably fair to say, however, that it is far easier to advise acceptance of colostomy than it is for the patient to resign himself to it. Only once has a patient hunted and threatened me with a gun. That patient had a colostomy performed in this clinic because of acute obstruction caused by

an irremovable malignant lesion in the left colon. He demanded that the colostomy be closed. I thought he was unreasonable; he thought we were, because we failed to comply with his wishes.

It is to be admitted that postoperative complications are more frequent in patients undergoing ampullary resection than in those accepting the abdominoperineal operation. A defect in the suture line with a temporary retrorectal fistula is a rather common complication. The length of the postoperative hospital stay in this group of patients has been long, made so essentially by necessity for supplemental colostomy in a number of the patients. In the earlier series reported, the average postoperative hospital stay for primary resection of the colon and rectosigmoid was 14.3 days. That figure has not been computed for the 78 colon resections reported herein, but it is undoubtedly shorter because the majority of patients having resections of the colon through oblique or transverse incisions are now leaving hospital before the tenth postoperative day. A trying complication, in a few instances of ampullary resection, has been a rectovaginal fistula in the female. I have the impression, however, that more frequent coincident excision of the uterus and the upper portion of the vagina in the instance of adherent tumors will eliminate this hazard. Under no circumstances should drainage be established through the vagina in ampullary rectal resection.

Despite the complication of a temporary retrorectal fistula, which has been dealt with in the majority of more recent cases solely by provision for perineal drainage just anterior to the coccyx, I have the impression that ampullary resection can be done at risks not far out of line with those run by patients undergoing the abdominoperineal operation.

Time will indicate whether the ultimate results of this operation, evaluated on the score of 5 year or longer periods of survival without evidence of recurrence, are as good in properly selected cases as in the more radical abdominoperineal operation. That the abdominoperineal operation is a better procedure for low-lying lesions and, particularly, in large fixed circumferential low-lying lesions in which the opportunity for lateral lymphatic spread of the tumor is great, already has been admitted.

Perhaps in no type of cancer would efforts at instruction of the public in the early recognition of the symptoms of rectal cancer prove more helpful. Were it not for the confusion of bleeding hemorrhoids, every patient with rectal bleeding should come for examination to have the diagnosis of rectal cancer disproved. Much more can still be done to instruct the public on this score. Granted early diagnosis, a far larger number of patients could have ampullary resection with sphincter preservation rather than the abdominoperineal operation and colostomy. In a study of 1,401 cases of cancer of the rectum and rectosigmoid, Bacon (1938) in reviewing the location of 1,401 carcinomas in the pelvic colon and rectum, stated the distribution to be as follows: sigmoid 22.5 per cent; rectosigmoid 16.5 per cent; rectum 56.1 per cent; and anal canal 4.9 per cent. Only 19.1 per cent of these 1,401 neoplasms were less than 2 inches from the anorectal line. Dividing the rectum into three parts of which the lowest is the shortest and the upper the longest portion, Dukes (1940) found in a group of 915 rectal cancers, 36.6 per cent in the lower third; 32.6 per cent in the middle; and 30.8 per cent in the upper third. Inasmuch as ampullary resection can be carried out in the midrectum quite regularly and as low as 5 centimeters from the anus in suitable instances, particularly in thin women with a deep cul-de-sac, in instances of rectal carcinoma diagnosed early, the method would appear to have a wide range of applicability. In this clinic, ampullary resection has reduced materially the number of abdominoperineal operations; however, as has been indicated, we already have learned that the method has no place in low-lying lesions in juxtaposition to the levatores, and, particularly, in large fixed low-lying lesions.

COMBINED BARIUM AND PROCTOSCOPIC EXAMINATIONS

An item not to be forgotten in all colonic and rectal operations for malignant growths is that excision of an extra segment of bowel occasionally brings with it an unexpected polyp. In this clinic, therefore, all patients in

whom cancer of the colon is diagnosed by the roentgenologists undergo proctoscopic examination prior to operation. Similarly all patients in whom cancer of the rectum is diagnosed by the proctologist receive a barium enema to exclude the possibility of another malignant tumor or a polyp more proximally situated. All lesions within the reach of the sigmoidoscope also are subjected to diagnostic biopsy before operation is undertaken. Mayo and Schlicke (1942) stated that in 100 consecutive autopsies on patients between 22 and 80 years (average 54.7 years), dying of conditions unrelated to the colon, polyps were found 16 times and in 8 of these beginning cancerous changes were present.

SUMMARY

Primary resection, employing the closed anastomosis without antecedent complemental or supplemental colostomy, is used in this clinic as the operation of choice in all unobstructed malignant growths of the colon. Similarly, in suitable lesions in the ampulla of the rectum, primary resection (closed anastomosis) can be carried out satisfactorily. Whereas primary healing and, in consequence, short postoperative hospital stays are the rule in primary resection of the colon and rectosigmoid, in ampullary rectal resection, primary healing is not usual. This circumstance is owing to the sole dependence of the surviving lower rectal segment upon the inferior hemorrhoidal arteries, following division of the superior and middle hemorrhoidal vessels and mobilization of the rectum, which ordinarily deprives the lower rectal segment of the branches coming from the middle sacral artery as well; nevertheless, ampullary rectal resection with primary anastomosis usually can be done without colostomy, provision being made for perineal drainage of the presacral space which may become infected because of a defect in the suture line. Supplemental colostomy, however, has been necessary in several instances to deal quickly and more effectively with the item of posterior space infection.

The chief defect in the operation of ampullary resection is that it is not a good operation for large fixed low-lying Dukes' group C malignant growths. Whereas, the tumor can be mobilized and a satisfactory anastomosis made even in such cases, the opportunity for local recurrence is great in that the operation does not remove the levator muscles and the lateral zones of lymphatic spread. In suitable small low-lying lesions and in most lesions of the upper rectum, this experience with rectal resection suggests that it is a satisfactory operation for cancer. Ampullary resection also has been done for ulcerative colitis.

Sphincteric function, in most cases, has been good after ampullary resection. The primary closed suture method appears to be the most satisfactory operation.

The hospital mortality for primary resection of the colon and rectosigmoid has been 5 per cent; and for ampullary rectal resection 7.4 per cent.

Secondary excision of hepatic metastases is described.

REFERENCES

1. ABEL, A. Surg. Gyn. Obst., 1935, 60: 481.
2. BABCOCK, W. W. Surg. Gyn. Obst., 1932, 55: 627.
3. BABCOCK, W. W., and BACON, H. E. Surg. Clin. N. America, 1942, 22: 1631.
4. BACON, H. E. Anus, Rectum and Sigmoid Colon; Diagnosis and Treatment. P. 566. Philadelphia: J. B. Lippincott Co., 1938.
5. BRODERS, A. C., BUIE, L. A., and LAIRD, D. R. J. Am. M. Ass. 1940, 115: 1066.
6. COLLER, F. A., KAY, B., and MACINTYRE, R. S. Surgery, 1940, 8: 294.
7. DENNIS, C. Surgery, 1944, 15: 713.
8. DIXON, C. F. Personal communication, November, 1944.
9. DRUMMOND, H. Brit. J. Surg., 1914, 1: 677.
10. DUKES, C. E. J. Path. Bact., Lond., 1932, 35: 323.
11. Ibid., 1940, 50: 527.
12. GABRIEL, W. B., DUKES, C. E., and BUSSEY, H. J. R. Brit. J. Surg., 1935, 23: 395.
13. GILCHRIST, R. K., and DAVID, V. C. Ann. Surg., 1938 108: 621.
14. GRAHAM, R. R. Surgery, 1940, 8: 257.
15. JONES, D. F. Ann. Surg., 1929, 90: 675.
16. Idem. South. M. J., 1936, 29: 339.
17. MCKELVEY, J. L. Personal communication, September, 1944.
18. MAYO, C. W., and SCHLICKE, C. P. Surg. Gyn. Obst. 1942, 74: 83.
19. MILES, W. E. Cancer of the Rectum. London: Harrison & Sons, 1926.
20. Idem. Surg. Gyn. Obst., 1931, 52: 350.
21. NORBURY, L. E. C. Carcinoma of the Rectum with Special Reference to Its Pathology and Treatment Based on a Number of Cases at St. Marks' Hospital during the Past 10 Years. P. 76. London: H. K. Lewis & Co., 1941.
22. PEMBERTON, J. DE J., and DIXON, C. F. Surg. Gyn. Obst., 1934, 58: 462.
23. POPE, C. E., and BUIE, L. A. Tr. Am. Proct. Soc., 1930, 30: 78.
24. QUENU, E. Bull. Soc. anat. Paris, 1893, 7: 703.

25. RANKIN, F. W., and GRAHAM, A. S. Am. J. Surg., 1939, 46: 18.
26. SEEFELD, P. H. Spread of Carcinoma of the Rectum; a Study of Invasion of Lymphatics and Blood Vessels. Unpublished Mayo Foundation Master's Thesis, 1942.
27. STEWARD, J. A., and RANKIN, F. W. Arch. Surg., 1933, 26: 843.
28. SUDECK, P. Muench. med. Wschr., 1907, 54: 1314.
29. VARCO, R. L. Unpublished Ph. D. Thesis, University of Minnesota, May, 1944.
30. VARCO, R. L., and KOLOUCH, F., JR. Staff Meet. Bull., Hosp. Univ. Minnesota, Jan. 14, 1944.
31. WANGENSTEEN, O. H. J. Lancet, 1937, 57:1.
32. Idem. Surg. Gyn. Obst., 1942, 75: 675.
33. Idem. Arch. Surg., 1943, 46: 877.
34. Idem. Surgery, 1943, 14: 403.
35. Idem. J. Lancet, 1944, 54: 178.

METABOLIC ALTERATIONS FOLLOWING THERMAL BURNS

II. Changes in the Plasma Volume and Plasma Protein in the Convalescent Phase

WILLIAM E. ABBOTT, M.D., JOHN W. HIRSHFELD, M.D., and
FRIEDA L. MEYER, Ph.D., Detroit, Michigan

THE purpose of this paper is to present the alterations that occurred in the plasma volume, the "available (thiocyanate) fluid" volumes, the total circulating plasma protein, the total circulating albumin, and the hematocrit value of burned dogs during the convalescent period. It has been shown (8, 16) that during the first 36 to 48 hours after burning there is a diminution in the plasma volume. Because of this diminution and because of the questionable accuracy of plasma volume determinations during shock, the present studies were confined to animals that had fully recovered from the immediate shock phase.

MATERIALS AND METHODS

Normal adult female mongrel dogs were employed. The dietary management and the preparation of the animals are described in another publication (24). (Animals 7 and 8 were simultaneously employed in both studies.) Control blood studies were obtained after the animals had been maintained on a constant diet from 3 to 4 weeks. Following the burn all of the animals except dog 9 were able to continue on the same diet.

All blood samples were obtained in the morning after a 12 to 18 hour fast. Heparin was used as the anticoagulant. Undue stasis was avoided, and greased syringes were employed to prevent hemolysis. Hematocrits were done in duplicate in Sanford-Magath (27) cell volume tubes; the total plasma protein concentration was done in duplicate by the micro-Kjeldahl technique. Plasma albumin concentration was determined by the method advocated by Hill and Trevarrow except that five times the amount of plasma and globulin precipitant was employed.

The plasma volume and "available (thiocyanate) fluid" volume were determined by injecting simultaneously 8.68 milligrams of Evans blue dye[1] (T-1824) and 483 milligrams of sodium thiocyanate[1] according to the direct method of Gregersen and Stewart as adapted to the photoelectric colorimeter by Gibson and Evelyn. The disappearance slope of the Evans blue dye was determined by four points and was found to vary only slightly during the control or postburn studies.

The total circulating plasma protein and plasma albumin were calculated by multiplying the plasma volume by the plasma protein and the albumin concentrations per cubic centimeter, respectively. The total blood volume was calculated from the following formula:

$$\text{Blood volume} = \frac{\text{Plasma volume}}{100 - \text{Hematocrit}} \times 100.$$

Since it is generally appreciated that the true blood volume cannot be determined in this manner (14), no absolute conclusions will be based on these findings, but it was thought that the percentage changes might be of some interest because of the alterations that occurred in the plasma volume and in the hematocrit.

A few days after the control blood studies had been obtained, the animals were burned under intravenous nembutal anesthesia. They were burned over the thorax and abdomen, which had previously been shaved. Irons with a burning area of 12.57 square centimeters were employed, being heated in boiling

From the Department of Surgery, Wayne University College of Medicine. The work described in this paper was done in part under a contract recommended by the Committee on Medical Research between the Office of Scientific Research and Development and Wayne University. It was aided in part by a grant from the Theodore A. McGraw Fund for surgical research.

[1]The ampuls were kindly supplied by the Kimble Glass Company and prepared by the College of Pharmacy of Wayne University.

water to approximately 100 degrees C. and applied for 3 seconds. A very deep second or third degree burn was produced over approximately 20 per cent of the body, as calculated from the formula of Cowgill and Drabkin. The burned area remained dry and hard for 4 or 5 days. Sloughing usually began after this, and the burn remained open a little over 2 weeks. Complete healing occurred in almost every instance within 3 weeks. The burns were not covered with dressings or medication.

RESULTS

All of the animals consumed their full diet after burning, with the exception of dog 9. She consumed the full ration until the 9th day, when marked diarrhea occurred; a reduced diet was taken until the 12th day, when the animal began eating normally again. All of the animals presented in this paper had loose stools in the postburn period, but only dog 9 developed severe diarrhea. Nitrogen balance studies showed that a negative nitrogen balance occurred immediately after burning and persisted for 15 days (24). All of the animals lost 15 to 20 per cent of their control weight, a loss not repaired as long as the diet was kept constant. When the intake was increased, there was a rapid return of weight to normal.

Although hematocrits were not done on all the animals during the acute shock phase (the first 48 hours), those that were done showed a fairly marked hemoconcentration. By the end of the first week the hematocrits had fallen to subnormal values, and they remained low until the plasma volumes showed a return to approximately the control value.

As shown in Table I all the dogs, except dog 9, exhibited a rise in their plasma volumes that persisted for 40 to 90 days. In dog 9 an initial rise occurred with a subsequent fall. This can be explained by the loss of fluid and electrolytes in the stool (diarrhea). If the plasma volume is figured in cubic centimeters per kilogram of body weight, the increase is even more pronounced. The plasma protein concentrations showed moderate fluctuations and apparently were not altered greatly by the period of negative nitrogen balance. In fact, during and after this period, a decided increase was noted in the total circulating plasma protein, as much as 41 per cent in one instance. This increase was chiefly due to an increase in the globulin fraction. The plasma albumin concentration as a rule showed a decrease; the total circulating albumin showed a temporary initial rise followed by a decrease, with the exception of dog 9. These changes did not in any way seem to parallel the increase or decrease of the plasma volume.

In dogs 6 and 7 an edema of the extremities was present and persisted for 10 to 12 days although the animals were not burned in these regions nor over the region of the vessels leading to the extremities. The actual "available (thiocyanate) fluid" volume (roughly the extracellular fluid volume) was increased in dogs 6 and 7 but not to a great extent. If the thiocyanate volume is figured in cubic centimeters per kilogram, the values showed a consistent marked elevation. It is evident, therefore, that when a loss of weight occurred, the body solids were lost in greater proportions than was fluid and thus there was a relative water retention. The other two animals also showed an initial rise in the "available (thiocyanate) fluid" but no clinical evidence of edema.

DISCUSSION

Shearburn (28) has shown that there is a gradual decrease in the plasma volume and protein concentration in animals maintained on a fluid and food intake adequate except for protein. Thus in his animals there was a fairly marked fall in the total circulating plasma protein. This change has also been demonstrated in patients who were on a deficient food intake (1). Our burned dogs exhibited a 2 to 3 week period of fairly marked negative nitrogen balance and weight loss, yet uniformly they had an increase in the total circulating plasma protein and plasma volume. It would thus appear that the formation or mobilization of plasma protein is not immediately dependent on the state of nitrogen balance.

The animals showed a decrease in the circulating red cell mass, but because of an increase in the plasma volume, there were smaller fluctuations in the total blood volume. In 1923 Marriott pointed out that anemia usually followed the correction of a state of de-

TABLE I

Days post-burn	Wt. in kgm.	Hema-tocrit	Plasma protein concen-trations Gm/100 c.c.	Plasma albumin concen-trations Gm/100 c.c.	Plasma volume				%Change in blood volume	%Change in circulating protein		Available (Thiocyanate) fluid volume			
					c.c.	Percent Change	c.c./ kgm.	%Change per kgm.		Plasma protein	Plasma albumin	c.c.	%Change	c.c./ kgm.	%Change per kgm.
Dog 6															
0	18.73	55	6.63	4.05	928		50					6032		322	
4	18.06	43	6.36	4.01	1121	+21	62	+24	− 5	+16	+20	7104	+17	393	+24
9	17.16	45	6.62	2.55	1179	+27	69	+38	+ 4	+27	−20	6189	+ 2	361	+12
13	16.58	42	6.48	2.51	1149	+24	69	+38	− 2	+21	−23	6143	+ 2	371	+15
20	16.81	46	7.17	2.66	1083	+17	64	+28	− 3	+26	−23	6143	+ 2	366	+14
27	16.93	48	7.35	3.32	1120	+21	66	+32	+ 4	+34	− 1	6007	0	355	+10
35	17.16	45	7.40	2.79	1083	+17	63	+26	− 3	+30	−20	5832	− 3	340	+ 6
44	17.38	43	7.48	3.29	1023	+11	59	+18	−13	+24	−10	5918	− 2	340	+ 6
68	16.55	54	6.60	4.02	903	− 3	54	+ 8	− 5	− 3	− 3	5622	− 6	340	+ 6
81	17.73	52	6.67	3.59	931	0	53	+ 6	− 6	+ 1	−11	5422	−10	306	− 5
90	18.10	50			983	+ 6	54	+ 8	− 5						
120	19.77	53	6.54	3.59	983	+ 6	50	0	+ 1	+ 5	− 6	6235	+ 3	315	− 2
Dog 7															
0	19.05	54	6.38	3.90	952		50					6031		317	
4	18.18	47	6.47	3.68	1254	+32	69	+38	+14	+34	+24	6376	+ 6	350	+10
9	17.28	44	6.39	2.86	1243	+31	72	+44	+ 7	+31	− 4	6522	+ 8	377	+19
13	16.35	32	5.86	2.47	1254	+32	77	+54	+11	+21	−16	6625	+10	405	+28
20	16.35	39	7.11	3.04	1129	+19	69	+38	−10	+32	− 7	6007	−0.4	365	+15
27	16.47	45	7.11	3.64	1111	+17	67	+34	− 2	+30	+ 9	6053	+0.4	367	+16
35	16.69	44	6.48	3.43	1032	+ 9	62	+24	−11	+10	− 5	6143	+ 2	368	+16
44	17.16	48	6.24	3.52	1044	+10	61	+22	− 3	+ 7	−0.1	6099	+ 1	355	+12
81	16.12	52	5.88	3.61	999	+ 5	62	+24	+ 7	− 3	− 3	5748	− 5	357	+13
90	17.50	48			1083	+14	62	+24	+ 8						
120	19.53	52	6.37	3.74	1102	+16	56	+12	+11	+16	+11	6833	+13	350	+10
Dog 8															
0	12.95	47	6.23	3.61	694		54					4080		315	
4	12.14	38	6.91	3.37	807	+16	66	+22	+0.5	+29	+ 9				
9	10.91	37	6.12	2.92	768	+11	70	+30	− 7	+ 9	−10	4171	+ 2	344	+ 9
20	10.32	31	6.34	3.02	755	+ 9	73	+35	−16	+11	− 9	4031	− 1	391	+24
29	10.22	40	6.34	3.22	734	+ 6	72	+33	− 7	+ 8	− 6	4080	0	399	+27
53	10.45	44	6.16	2.72	612	−12	59	+ 9	−16	−13	−33	3946	− 3	378	+20
72	10.45	45	6.15	3.82	639	− 8	61	+13	−11	+ 9	− 3	3946	− 3	378	+20
90	13.29	41	6.01	3.65	709	+ 2	53	− 2	− 8	+ 1	− 3	4458	+ 9	335	+ 6
Dog 9															
0	11.59	41	6.14	2.56	670		58					4171		360	
4	11.47	41	6.29	2.61	783	+17	68	+17	+17	+20	+19				
9	10.57	31	5.09	2.27	869	+30	82	+38	+11	+ 7	+15	4518	+ 8	427	+19
20	7.73	37	8.28	4.21	701	+ 5	91	+57	− 2	+41	+72	3348	−20	433	+20
29	7.95	32	6.99	3.94	639	− 5	80	+38	−17	+ 9	+47	3638	−13	457	+27
41	8.18	37	6.44	2.80	596	−11	73	+26	−17	+ 7	− 3	3811	− 9	462	+28
53	8.18	36	6.43	2.96	652	− 3	80	+38	−10	+ 2	+12	3901	− 6	477	+33
72	8.15	38	6.43	2.81	617	− 8	76	+31	−12	− 3	+ 1	3735	−10	458	+27
90	10.68	37	5.76	3.03	652	− 3	61	+ 5	− 9	− 8	+16	4366	+ 5	409	+14

hydration. Shen, Ham, and Fleming have shown that anemia is present in the convalescent phase of burns because of an accelerated breakdown of red cells due to an increased fragility.

Our data also show a definite diminution in the red cell mass. Whether this is entirely due to an increased breakdown of red cells or in part a result of the crowding out of red blood cells by the increased plasma volume is not definitely known. Conversely, we are unable to say whether the increase in the plasma volume is due to an attempt to compensate for the decrease in red cells or whether it is caused in part by retention of fluid and electrolytes. Peters and Van Slyke; and Warren, Merrill, and Stead have stated that often a compensatory rise in the plasma volume occurs when anemia is present, but since there is disagreement on this point (3), the anemia seen in our burned animals may not be the sole explanation for the rise in the plasma volume.

Although the plasma volume was increased in most instances, there was interestingly a decrease in the total circulating plasma albumin, which accounts for the major osmotic pressure of the protein fraction. Cope recently stated that an increased plasma volume apparently occurs 4 to 5 days after a burn and intimates that this may be due to the reabsorption of previously lost protein. That the rise in plasma volume is not due solely to the reabsorbed protein seems likely. In dog 9 the amount of total circulating protein and albumin was markedly increased when the volume showed a precipitous fall. Also the fact that the rise in the plasma volume persists for weeks makes this theory unlikely. Thus the increase in the plasma volume must be largely due to a retention of either water or electrolytes or both.

Because of the findings in the present study and because of the increasing tendency to employ electrolyte solutions in the treatment of shock (2, 11, 25), it seems worth reconsidering the factors that influence the size of the plasma volume. In the normal individual it has been shown (17, 18) that the osmotic effect of the protein fraction is extremely important. The osmotic pressure exerted by the proteins, especially albumin, is largely responsible for the reabsorption of water into the vascular system. In the healthy subject the protein is almost entirely confined to the vascular bed and to the intracellular space, and there is approximate osmotic equality of the electrolytes within the cell, the interstitial space, and the plasma. Thus a slightly higher solute concentration within the plasma and intracellular phase is maintained because of the presence of the protein molecules. It should be remembered, however, that the electrolytes are present in much greater amounts than is protein, and since the amount of water present in the body compartments is dependent on the total solute concentration (colloids and electrolytes), the electrolytes are much more important than are the colloids in determining the total amount of body water (20). In fact it has been stated by Van Slyke that the osmotic effect of the protein molecules is so slight when one is considering total body water that it can be almost neglected. It seems probable, therefore, that the alterations noted during the convalescent phase of these burned animals is largely governed by the fluid and electrolyte disturbances.

From other experiments (22, 32, 33) it is also evident that the size of the plasma volume in the diseased state is often not dependent on the plasma protein concentration. It should be recalled that the intraperitoneal injection of a solution of 5 per cent dextrose into normal dogs with the withdrawal of the same amount of fluid 4½ hours later produces a marked increase in the plasma protein concentration, but this even in the face of an adequate water and caloric intake will not restore the plasma volume if sufficient electrolytes are not present (22).

The importance of sodium was recently emphasized by Fine, Frank, and Seligman, who showed that the intravenous administration of a 25 per cent solution of albumin into animals suffering from tourniquet shock was not of benefit unless a physiologic solution of sodium chloride was given by stomach tube or intravenously.

The work of Warren, Merrill, and Stead (32) has also shown that a normal plasma volume may be obtained in shocked animals even when the protein concentration and total

circulating plasma protein is markedly diminished by increasing the extracellular fluid volume (tissue tension). Thus it is evident that the size of the plasma volume in disease is not dependent on the protein concentration alone but is governed by the following factors: (1) the total solute concentration of the extracellular fluid volume and the available water, (2) the osmotic pressure of the plasma minus the osmotic pressure of the interstitial fluid, and (3) the blood filtration pressure minus tissue tension. Coller, Campbell, Vaughan, Iob, and Moyer have pointed out that at certain times the kidneys are unable to excrete electrolytes and water in normal amounts and that the inability to excrete such products may lead to a marked retention of body fluid when the circulatory mechanisms aforementioned are not grossly abnormal.

Studies by Davidson on patients with severe burns showed that chloride was excreted in only small amounts. McIver re-emphasized this fact after having administered large amounts of a physiologic solution of sodium chloride. Trusler, Egbert, and Williams stressed the undesirable effects of large volumes of water in burned patients and experimentally were able to produce "water intoxication" by excessive administration. It has also been shown that a fall in the extracellular sodium concentration (9, 23) causes an intracellular shift of water, and since this condition and acidosis often exist during the shock and convalescent phases of a severe burn, it would not seem desirable to give large quantities of water nor a physiological solution of sodium chloride. Solutions with an electrolyte make-up similar to that of plasma that would not upset the body's normal electrolyte pattern and would combat alterations in the acid-base balance, would thus appear to be desirable during the period of shock. In the immediate postshock phase it would then seem advisable to give solutions and food that would have the mineral and food value needed especially for cellular repair and that at the same time would gradually help rid the body of any excess water.

CONCLUSIONS

1. Following the shock phase, burned animals that were maintained on an intake of food identical with that consumed before injury show a decided rise in their plasma volumes above the normal.

2. Since a state of overhydration is manifested during the convalescent phase by the increase in the plasma volume and "available (thiocyanate) fluid" volume per kilogram of body weight, it does not seem advisable to give excessive quantities of fluid during the postshock period. Such an overaccumulation of fluid may undoubtedly lead to some of the so called "toxemic" deaths. Adequate urinary output should be maintained and diuresis en couraged.

3. A marked increase in the total circulating plasma proteins was present although a marked negative nitrogen balance existed for 2 to 3 weeks.

4. A moderate decrease in the plasma albumin concentration and in the total circulating albumin occurred when the plasma volume increased.

5. A definite anemia was present in the convalescent phase because of an actual decrease in the circulating red cell mass.

REFERENCES

1. ABBOTT, W. E., and MELLORS, R. C. Arch. Surg., 1943, 27: 277–288.
2. ALLEN, F. M. Am. J. Surg., 1943, 62: 80–104.
3. BOCK, A. V. Arch. Int. M., 1921, 27: 83–101.
4. COLLER, F. A., CAMPBELL, K. N., VAUGHAN, H. H., IOB, L. V., and MOYER, C. A. Ann. Surg., 1944, 119: 533–542.
5. COPE, O. J. Am. M. Ass., 1944, 125: 536–543.
6. COWGILL, G. R., and DRABKIN, D. L. Am. J. Physiol., 1927, 81: 36–61.
7. DAVIDSON, E. C. Arch. Surg., 1926, 13: 262–277.
8. DUNPHY, J. E., GIBSON, J. G., II, and KEELEY, J. L. Surg. Gyn. Obst., 1941, 72: 823–833.
9. EICHELBERGER, L., and HASTINGS, A. B. J. Biol. Chem., 1937, 118: 205–218.
10. FINE, J., FRANK, H. A., and SELIGMAN, A. M. J. Clin. Invest., 1944, 23: 731–741.
11. FOX, C. L. J. Am. M. Ass., 1944, 124: 297–312.
12. GIBSON, J. G., II, and EVELYN, K. A. J. Clin. Invest., 1938, 17: 153–158.
13. GREGERSEN, M. J., and STEWART, J. D. Am. J. Physiol., 1939, 125: 142–152.
14. HAHN, P. F., ROSS, J. F., BALE, W. F., BALFOUR, W. M., and WHIPPLE, G. H. J. Exp. M., 1942, 75: 221–232.
15. HILL, R. M., and TREVARROW, V. J. Lab. Clin. M., 1941, 26: 1838–1849.
16. KEELEY, J. L., GIBSON, J. G., II, and PIJOAN, M. Surgery, 1939, 5: 872–895.
17. KROGH, A. The Anatomy and Physiology of Capillaries. Rev. ed. New Haven: Yale University Press, 1929.
18. LANDIS, E. M. Physiol. Rev., 1934, 14: 401–481.
19. MARRIOTT, W. M. Physiol. Rev., 1923, 3:275–294.

20. McCance, R. A. Lancet, Lond., 1936, 230: 704–710.
21. McIver, M. A. Ann. Surg., 1933, 97: 670–682.
22. Mellors, R. C., Muntwyler, E., Mautz, F. R., and Abbott, W. E. J. Biol. Chem., 1942, 144: 785–793.
23. Mellors, R. C., Muntwyler, E., and Mautz, F. R. J. Biol. Chem., 1942, 144: 773–784.
24. Meyer, F. L., Joseph, S., Hirshfeld, J. W., and Abbott, W. E. (In press).
25. Moyer, C. A., Coller, F. A., Iob, V., Vaughan, H. H., and Marty, D. Ann Surg., 1944, 120: 367–376.
26. Peters, J. P., and Van Slyke, D. D. Quantitative Clinical Chemistry. Vol. I: Interpretations. Baltimore: The Williams & Wilkins Co., 1931.
27. Sanford, A. H., and Magath, T. B. J. Lab. Clin. M., 1929, 15: 172–173.
28 Shearburn, E. W. Surg. Gyn. Obst., 1942, 74: 343–347.
29. Shen, S. C., Ham, T. H., and Fleming, E. M. N. England J. M., 1943, 229: 701–713.
30. Trusler, H. M., Egbert, H. L., and Williams, H. S. J. Am. M. Ass., 1939, 113: 2207–2213.
31. Van Slyke, D. D., Wu, H., and McLean, F. C. J. Biol. Chem., 1923, 56: 765–849.
32. Warren, J. V., Merrill, A. J., and Stead, E. A. J. Clin. Invest., 1943, 22: 635–641.
33. Warren, J. V., and Stead, E. A. Arch. Int. M., 1944, 73: 138–147.

THE ROUTINE USE OF PROTEIN DIGEST INTRAVENOUSLY FOLLOWING MAJOR SURGICAL PROCEDURES

HERBERT H. DAVIS, M.D., F.A.C.S., Omaha, Nebraska

IN RECENT years it has become a routine procedure for surgeons to give fluids, salts, and carbohydrates intravenously following major surgical procedures. The importance of vitamins in maintaining normal physiology has also been recognized. Proteins have been found to be of great value, but their use has been neglected since a safe intravenous preparation has been made available only within the past few years.

In 1937 Elman (9) reported results of experiments on animals in which he showed that intravenous amino acids are utilized in the regeneration of serum protein. In 1938 (10) he reported the first use of hydrolyzed protein in humans as a means of maintaining positive nitrogen balance. In 1939 Cox and Mueller published their findings on the use of an enzymic digest in maintaining a positive nitrogen balance. Shohl, Butler, Blackfan, and MacLachlan were able to maintain infants in positive nitrogen balance by the oral administration of enzymic casein hydrolysate. Farr and MacFayden (15), and Farr, Emerson and Futcher (14), working with nephrotic children, found intravenously injected hydrolysate a complete substitute for dietary protein.

In 1942 Brunschwig and associates (3), discussed means of preventing nitrogen loss following operations by parenteral administration of protein digest. Continuing their studies (4) they found that intravenous digest was utilized as effectively as orally ingested protein. Landesman and Weinstein concluded that intravenous protein digests were rapidly absorbed from the blood stream by the body tissues.

Elman (12) demonstrated positive nitrogen balance, as well as regeneration of serum albumin in protein depleted dogs. They could assimilate as much as 1.75 grams of nitrogen (11 gm. protein) per kilogram of body weight per day. Abbott and Mellors established that adequate amounts of amino acids parenterally would maintain positive nitrogen balance when sufficient calories were given. Brunschwig (4), and many others verify this finding. Elman (13), reviewing the previous work regarding intravenous protein digests, stated that he has injected a mixture of equal parts of glucose and hydrolyzed protein and has frequently observed positive nitrogen balance even when the caloric intake was far from adequate to meet daily needs.

Why is protein necessary? Mueller, Fickas, and Cox found that when subjects were fed diets complete in all elements except protein, within 48 hours they developed severe lassitude and asthenia which were rapidly corrected by the ingestion of protein. They established the minimum requirements of enzymic casein hydrolysate to be between 0.4 and 0.7 gram per kilogram of body weight per day. Mulholland, Co Tui, and associates noted that, in a series of gastric resections, jejunal alimentation immediately following operation alleviated most of the postoperative asthenia and accelerated convalescence.

Protein is very essential for the healing of wounds. Clark found that on a high fat diet wound healing did not begin for 6 days, on a mixed diet it began in 4 days, on a high carbohydrate diet the quiescent period of healing was 3 days, while on a high protein diet healing began at once. Thompson, Ravdin, and Frank, in 1938, found that on a low protein diet 8 of 11 dogs failed to heal abdominal incisions. In 1940, Ravdin stated that cellular repair and regeneration require protein, and that in the absence of adequate amounts of essential amino acids growth cannot take place. In studying the plasma protein levels in 35 patients with decubitus ulcers, Mulholland, Co Tui and associates, noted that all had hypoproteinemia, and in general, the largest ulcers

From the Department of Surgery, University of Nebraska College of Medicine.

Read before the Western Surgical Association, Chicago, Illinois, December, 1944.

were in the patients with the most deficient proteins. They found that high caloric intake if low in protein had no effect on the healing of bed sores; there was continual weight loss, and nitrogen balance remained negative. On the other hand, a high protein diet resulted in a positive nitrogen balance and rapid healing of the ulcer. At this time I had a patient with a decubitus ulcer 4 centimeters in diameter which was enlarging in spite of very good nursing care. This man was then placed on a high protein diet (100 to 150 gm. protein per day) and in 12 days the ulcer was healed.

Distention and gas pains may be prevented or greatly lessened by the administration of adequate protein. In 1937 Mecray, Barden, and Ravdin, experimenting on animals, noted that as serum proteins decreased in concentration gastric emptying time was delayed. Ravdin found that with marked hypoproteinemia it took three times as long for the food to pass through the stomach and the small bowel.

An important function of the plasma proteins, especially of the albumin, is to control the balance of fluid between the capillaries and the tissue spaces. While the figures are variable and depend somewhat upon other factors, in general, edema is likely to appear when the plasma proteins are below 5.5 grams per 100 cubic centimeters or the albumin is below 3 grams per 100 cubic centimeters.

The globulin factor aids in the resistance to infection. Cannon, Chase, and Wissler (5) in 1943 demonstrated that the production of antibodies is only one-fifth to one-third as great in animals with protein deficits as it is when the proteins are normal. Cannon and Wissler with Woolridge and Benditt (6) found that normal human serum contains about 25 milligrams per 100 cubic centimeters of globulin, of this 8 milligrams or one-third, may be gamma globulin, and it is in this one-third that antibodies are found.

Our study is based upon the use of protein digest (amigen) in 203 surgical patients from my private practice in the first 10 months of 1944. At two hospitals amigen was given intravenously to most of the patients until they were able to take a soft diet by mouth. In another hospital I used no amigen but used glucose and physiological saline instead as a control.

The eating habits of normal man are well established. He eats three meals a day and does not wait until he feels exhausted before consuming the next meal. It is no more logical to go several days after operation without adequate nourishment. It is even more hazardous, since there is loss of blood and marked excessive breakdown of protein in the traumatized tissues. The postoperative lassitude and weakness have been attributed to the operation; however, may not the lack of nourishment be an important factor?

In a series of 32 appendectomy patients without peritonitis we gave amigen once or twice on the day of operation. The next day they were placed on soft diets. An average of 1,328 cubic centimeters of amigen and 62 cubic centimeters of other intravenous fluids were given each patient. Forty-three liters of amigen were administered and 5 per cent of these caused reactions in 2 patients. One was a patient with acute appendicitis and severe nephrosis. The preoperative pulse was 160, marked anasarca, and plasma protein was only 2.59 grams per 100 cubic centimeters. After the second infusion of amigen she was nauseated and vomited; this may have been due to the disease. She died of nephrosis 52 hours after operation. The other reaction was nausea without vomiting after the first infusion. There was no reaction after the second infusion. Routinely these patients sit up in 3 days and are dismissed in 5 days. They exhibit very little weakness.

Twenty-six herniorrhaphy patients were given an average of 2,038 cubic centimeters of amigen, and of the 55 liters infused, there was a distressing reaction in 2 per cent. One patient had nausea after the first of two infusions, which was probably not due to the infusion as she was nauseated at different intervals during the same day.

An average of 3,625 cubic centimeters of amigen and 376 cubic centimeters of other intravenous fluid were given to 28 cholecystectomy patients. In a total of 101 liters of amigen there was reaction to 4 per cent. One liter of amigen is given twice a day until nausea has ceased and the patient is ready to take a soft

diet. These patients are much stronger and are convalescing much more rapidly. Most of them now sit up in 5 days and return home in 7. Of the 3 reactions, there was a general malaise in a nervous patient in which the infusion was given in 2 hours and 30 minutes. Two had nausea. In the first it was given too rapidly, 2 hours and 20 minutes; the other probably was not due to the amigen as she was developing symptoms of a bowel obstruction for which she was again subjected to operation.

The pelvic operation group were treated the same as those with cholecystectomies, and the results were similar. An average of 2,993 cubic centimeters of amigen, 139 cubic centimeters of blood and plasma, and 265 cubic centimeters of other intravenous fluid were given to each patient. Of the 144 liters of amigen given, there were distressing reactions in but 4 per cent. There were 5 reactions of nausea and 1 of headache and dizziness. Four of the six reactions were due to too rapid an administration of amigen, 1 hour and 50 minutes to 2 hours and 30 minutes. These were all reactions to infusions given in the early part of this study. None had reactions with each infusion of amigen. One had reactions with 2 of the infusions received, and the others in only one.

In a group of 17 thyroidectomy patients an average of 2,117 cubic centimeters of amigen, and 1,264 cubic centimeters of other intravenous fluid were given. Of the 36 liters of amigen infused there were distressing reactions to 11 per cent. Two patients reported nausea, and one patient had emesis after two separate infusions. These patients were all rather thyreotoxic.

Fifteen mastectomy patients were given an average of 1,266 cubic centimeters of amigen and 66 cubic centimeters of other intravenous fluid. Distressing reactions were reported after the use of 5 per cent of the 19 liters of amigen. Dizziness was reported by 1 patient; it was not given too rapidly and the patient was not otherwise distressed. These patients were placed on a soft diet within a short time after operation.

In a group consisting of 3 exploratory celiotomies, 2 liberations of adhesions, 1 gastroenterostomy, 2 leg amputations, 1 Kondoleon operation for elephantiasis, an average of 22 cubic centimeters of amigen was given preoperatively to each patient. Postoperatively, they received an average of 4,555 cubic centimeters of amigen, 22 cubic centimeters of blood, and 777 cubic centimeters of other intravenous fluid. Of the exploratory celiotomies, one was an inoperable carcinoma of the gall bladder, another carcinoma of the rectosigmoid, and the third, carcinoma of the ovary with liver metastases. There were 2 deaths in this group, the carcinoma of the gall bladder and 1 of the leg amputations. In spite of an average of 5 infusions per patient there were no reactions in this group.

In the following four series, the favorable results of protein digest intravenously were quite marked because a longer time elapsed before the patients were able to resume eating. They were given amigen, 1 liter twice a day, until it was safe to begin mouth feedings. Their maintenance of strength and well-being was outstanding, and they did not develop edema. There was no need to give food by mouth until peritonitis had subsided and until bowel resections had quite healed.

In a group of 7 patients with peritonitis we gave an average of 6,326 cubic centimeters of amigen, 228 cubic centimeters of blood, 114 cubic centimeters of plasma, and 1,259 cubic centimeters of other intravenous fluid. Protein is especially indicated in peritonitis as there is considerable protein loss into the peritoneal exudate. In spite of the severity of illness in these patients only two had reactions; one was an 11 year old boy who suffered chills but no fever, and the other, a reaction following the fifth of six infusions. This infusion was given too rapidly; we later discovered 2 hours and 30 minutes to be too short a period for satisfactory infusion. Of the 45 liters given there were distressing reactions to 4 per cent.

In acute intestinal obstruction amigen is usually given preoperatively as well as after surgery. Three patients with acute intestinal obstruction were given, preoperatively, an average of 2,333 cubic centimeters of amigen and 5,166 cubic centimeters of other intravenous fluid, and, postoperatively, 8,666 cubic centimeters of amigen and 666 cubic centimeters of other intravenous fluid. Thirty-three

liters were administered and there was distressing reaction in 3 per cent. One patient reported having a reaction of bad taste, nausea, and emesis after an infusion. It is doubtful if it was due to the amigen as she was a very ill patient.

Ten patients upon whom gastric resections were done, mainly for carcinomas and benign ulcers, were given an average of 3,300 cubic centimeters of amigen, 50 cubic centimeters of blood, and 1,400 cubic centimeters of other intravenous fluid preoperatively. Postoperatively they received 10,000 cubic centimeters of amigen, 150 cubic centimeters of blood, and 1,200 cubic centimeters of other intravenous fluid. There were no reactions to any of the infusions in this group. About one-half of the patients with carcinomas are hypoproteinemic, as judged by the reports of Karl Meyer; Memorial Hospital, in New York (23); and the Brooklyn Cancer Institute (2).

CANCER PATIENTS

TOTAL BLOOD PROTEINS—GM. PER 100 C.C.

No. of patients		Normal range	Reported range	Percentage of patients below low level (6.5)
58	Meyer's studies	6.34—6.73	5.12–8.12	29.3
100	Brooklyn Cancer Institute	6.5 –8.	3.3 –9.6	55
100	Abel's studies	6.2 –6.9	3.9 –8.	59
10	Our studies	6.5 –7.5	5.01–7.56	50
268	Group average	6.38–7.28	4.3 –8.3	50.7

Therefore we correct anemia by blood transfusion and protein deficiency by protein, orally or intravenously, before operation. This group progressed remarkably well, with scarcely any complaints of weakness.

The colostomy group of 8 patients were mainly for carcinoma. It included obstructive resections of the sigmoid. In these the clamp is left on for 4 or 5 days until the risk of severe infection of the wounds is reduced to a minimum. Preoperatively, they were given an average of 62 cubic centimeters of blood, and 250 cubic centimeters of other intravenous fluid; postoperatively each received 10,000 cubic centimeters of amigen, 1,105 cubic centimeters of blood, and 1,312 cubic centimeters of other intravenous fluid. Eighty liters were administered with no distressing reaction. The patients' strength remained good, and with gastric suction there was practically no distention.

In giving 730 liters of amigen intravenously to 203 surgical patients, there were no severe reactions. Most of the reactions reported were in the early part of this study, 76 per cent occurring in the first 5 months when many of the infusions were given too rapidly. However, there were reactions to only 3 per cent of the 730 infusions. If a 3 hour period is allowed for an infusion of 1000 cubic centimeters of amigen we have little to fear from reactions.

A group of 50 patients were used as a control group during the time that we were making an investigation of the use of protein digest intravenously. They received glucose and physiological saline instead of amigen. They seemed to be weaker and slower in convalescing than those given protein digest.

It is realized that the conclusions drawn are based upon clinical impressions alone. Plasma protein determinations have been of no avail since definite changes do not occur within a span of a few days, consequently they are of value only in chronic deficits. Unfortunately, there is no method of measuring the tissue protein and this is approximately thirty times as much as the plasma protein. Except for research purposes, it is impractical to determine the total plasma volume; roughly, it is about one-twentieth of the body weight. Therefore in an average 70 kilogram man there is 1/20 of 70 kilograms or 3,500 grams of plasma. Plasma protein is normally 6.5 to 7.5 grams per 100 cubic centimeters. Taking an average of 7 per cent the total serum plasma is .07 times 3,500 grams which equals 245 grams. The total plasma volume is variable. For example, it is greatly reduced in dehydration or shock, and in such a state the total protein determination per 100 cubic centimeters may be considerably elevated, but because of the decreased plasma volume the plasma protein in the total amount of blood may be decreased. It is possible to get an estimate of plasma volume by determining the erythrocyte count, hemoglobin, and the specific gravity of the urine.

For a serum drop of 1 gram per 100 cubic centimeters the total drop in the plasma is approximately 35 grams. But as there is thirty times as much protein in the tissues, we must assume that the protein loss from the body would be 30 times 35 grams or 1,150 grams. This drop would require 2 or 3 weeks if no protein at all were given. It is evident why it requires so much protein to return a patient with a chronic deficit to normal.

CONCLUSIONS

The use of protein digest intravenously has been proved by various investigators to be safe and efficacious in promoting general well-being and strength, and as an invaluable aid in tissue building, wound healing, combating infection, maintaining fluid balance, osmotic pressure, and optimal gastric emptying.

In our use of intravenous protein digest in 203 patients, we found these results to be true; we endorse its safety as a therapeutic measure. We advocate the intravenous use of protein digest following major surgery as a routine measure, until such time as patients are able to take adequate nourishment by mouth, or until proper assimilation is assured.

Our patients are clinically improved; they are stronger, display more pleasant cheerful attitudes, and are able to be about sooner than those who are not given this treatment. They have a quicker return of appetite, are more vigorous and ambitious in assuming accustomed activity, and show much less fatigue.

REFERENCES

1. Abbott, W. L., and Mellors, R. C. Arch. Surg., 1943, 46: 277.
2. Abels, J. E., Ariel, I., Rekers, P., Pack, G., and Rhoads, C. P. Arch. Surg., 1943, 46: 844.
3. Brunschwig, A., Clark, D. E., and Corbin, N. Ann. Surg., 1942, 115: 1091.
4. Brunschwig, A., and Corbin, N. Surgery, 1943, 14: 298.
5. Cannon, P. R., Chase, W. E., and Wissler, R. W. J. Immun., Balt., 1943, 47: 133.
6. Cannon, P. R., Wissler, R. W., Woolridge, R. L., and Benditt, E. P. Ann. Surg., 1944, 120: 514.
7. Clark, A. H. Bull. Johns Hopkins Hosp., 1919, 30: 117.
8. Cox, W. M. Jr., and Mueller, A. J. Proc. Soc. Exp. Biol., N.Y., 1939, 42: 658.
9. Elman, Robert. Proc. Soc. Exp. Biol., 1937, 36: 867.
10. Idem. J. Am. M. Ass., 1939, 112: 796.
11. Idem. Ann. Surg., 1940, 112: 594.
12. Idem. J. Am. M. Ass., 1943, 122: 747.
13. Idem. Ann. Surg., 1944, 120: 350.
14. Farr, L. E., Emerson, K., Jr., and Futcher, P. H. J. Pediat., S. Louis, 1940, 17: 595.
15. Farr, L. E., and MacFayden, D. A. Proc. Soc. Exp. Biol., 1939, 42: 444.
16. Landesman, R., and Weinstein, V. A. Surg. Gyn. Obst., 1942, 75: 300.
17. Mecray, P. M., Jr., Barden, R. P., and Ravdin, I. S. Surgery, 1937, 1: 53.
18. Meyer, K. A., and Kozoll, D. D. Surg. Gyn. Obst., 1944, 78: 181.
19. Mueller, A. J., Fickas, D., and Cox, W. M., Jr. Bull. Johns Hopkins Hosp., 1943, 72: 110.
20. Mulholland, J. H., Co Tui, F., Wright, A. M., and Vinci, V. J. Ann. Surg., 1943, 117: 512.
21. Mulholland, J. H., Co Tui, F., Wright, A. M., Vinci, V. J., and Shafiroff, B. Ann. Surg., 1940, 112: 576.
22. Ravdin, I. S. Ann. Surg., 1940, 112: 776.
23. Robillard, G., and Shapiro, A. Arch. Surg., 1942, 44: 840.
24. Shohl, A. T., Butler, A. M., Blackfan, K. C., and MacLachlan, E. J. Pediat., S. Louis, 1939, 15: 469.
25. Thompson, W., Ravdin, I. S., and Frank, I. L. Arch. Surg., 1938, 36: 500.

DISARTICULATION OF THE INNOMINATE BONE FOR MALIGNANT TUMORS OF THE PELVIC PARIETES AND UPPER THIGH

EVERETT D. SUGARBAKER, M.D., F.A.C.S., and LAUREN V. ACKERMAN, M.D.,
Columbia, Missouri

THE operative removal of varying portions of the pelvis along with the subjacent lower extremity has now been occasionally practiced for approximately 50 years. Though a number of terms (interilioabdominal amputation; interilioabdominal disarticulation, interpelviabdominal amputation, interpelviabdominal disarticulation, interiliosacropubic disarticulation, hindquarter amputation, hemipelvectomy, transiliac amputation) have been applied to operations of this general character, we have chosen the simple descriptive above because it most closely fits the cases to be presented and constitutes what in our opinion is the ideal procedure in the majority of instances.

The first attempt to accomplish such a removal is generally credited to Billroth, who in 1891 undertook to treat a sarcoma of the pelvis by this means. His patient died several hours postoperatively. Several other unsuccessful tries by Jaboulay and by Cacciopoli then followed, but in 1895 Girard resected a sarcoma of the upper femur carrying his line of division well up into the pelvis and was able to keep his patient alive postoperatively. A year earlier he had successfully removed a portion of the pelvis in another patient, but this was done for a stump recurrence of a sarcoma of the upper femur following an earlier hip joint disarticulation. Since then an increasing number of reports have been collected from time to time by various authors (12, 18). In the most recent of these, Leighton collected 106 cases. The addition of 26 more, inclusive of the authors' cases, brings the total to 132. Of this group, 99 have been operated on for tumors of bone or soft parts in the region of the upper femur or pelvis, and it is with these that the present writing is concerned.

From the Departments of Surgery and Pathology, Ellis Fischel State Cancer Hospital.

In evaluating any operative procedure for malignant neoplasms, two primary factors must always be taken into consideration: the primary operative mortality and the ability of the operation to cure. The factor of disability should also be considered in any operation as mutilating as this one, for there is no doubt that the disability is considerable. To date no satisfactory prosthesis has been designed which will enable these patients to walk, and ambulation must be accomplished with the help of crutches.

Of the 99 cases listed, death occurred in 38 at the time of operation, a mortality rate of 38 per cent, and although the cause of death has not always been stated it seems apparent that shock was responsible for the great majority since death usually ensued either during or within a few hours of operation. With newer methods of treating this surgical complication, the mortality rate has dropped considerably. Prior to 1935, death occurred in 56 per cent of the recorded cases in the postoperative period, but in the past 10 years there have been only 6 postoperative deaths in the 42 patients operated upon, a mortality of 14 per cent. The average age of the group surviving operation was 35 years as compared to 40 years in the group which succumbed, additional reflection of shock as the major complication.

Attempts to evaluate the end-results have been somewhat discouraging, as the length of follow-up in many instances has been inadequate to draw any useful conclusions. Of 61 patients surviving operation and followed up 20 died of disease in 1 year, 2 up to 2 years, 1 each up to 3 and 5 to 9 years. Nine were clinically well up to 1 year, 6 up to 2 years,

2 up to 3 years, and 4 from 5 to 9 years. Sixteen were not followed at all. Unfortunately, of the 21 patients who were reported clinically well we do not know how many later died of disease, though it is apparent that most of these patients died of disease within 1 year of operation, and 12 of the patients had survived that period.

A variety of tumors were found in the 45 patients who were followed. There were 39 with tumors of the bone, 5 of the soft parts, and 1 metastatic carcinoma (thyroid), who was alive 1 to 5 years later. Of the tumors of bone, there were: 15 osteogenic sarcomas, 2 of the patients living 1 to 5 years; 1 each of the osteoblastic and osteolytic types; 2 periosteal chondrosarcomas, 3 living 1 to 5 years and 4 dead within the 5 year period; 3 chondromas, 1 a postoperative recurrence and all living 1 to 5 years; 1 each of Ewing's sarcoma, benign giant cell tumor and neuroblastoma, each of the 2 latter living 1 to 5 years. Of the tumors of the soft parts, 3 were of muscle origin and 2 of these were well 1 to 5 years; 1 extraosseous osteogenic; 1 unidentified. It is interesting to note that 2 of the 19 osteogenic sarcomas were living. Undoubtedly, the most favorable group consists of those in which the primary site of origin is in cartilage. It was difficult in some instances to determine accurately the existing pathology, and the classification occasionally had to be made on the basis of inadequate data.

ANATOMICAL STRUCTURES CONCERNED

In severing one side of the pelvis, the following structures must be divided: skin; muscles—(1) flat muscles of the anterior abdominal wall, (2) rectus abdominis, (3) ischiocavernosus, (4) quadratus lumborum, (5) iliopsoas, (6) gluteus maximus (sometimes saved), (7) pyriformis, (8) levator ani; ligaments—(1) iliolumbar, (2) sacrospinous, (3) sacrotuberous; vessels—external iliac artery and vein, deep epigastric, gluteals (unless the gluteus maximus muscle is to be spared), pudendal; nerves—branches of lumbar plexus; bone—symphysis pubis (or opposite pubic arch), sacroiliac joint (or sacral ala).

Structures to be carefully guarded are: (1) ureter, (2) bladder, (3) rectum.

PROCEDURE

Our experience has been confined to the use of continual spinal anesthesia (5). The needle is placed in the third lumbar interspace and is included with the lower portion of the novocain tubing in the operative field, so that it may be more closely guarded or replaced if necessary. Anesthesia is maintained at the level of the umbilicus. Transfusion is carried out throughout the entire procedure into the opposite upper extremity and small doses of pentothal are periodically given as needed to maintain light sleep. The patient is placed in an oblique position on the table and bolstered with sand bags. This position permits sufficient mobility for easy exposure both anteriorly and posteriorly.

An incision is made from the posterior superior iliac spine to the symphysis ending just above the iliac crest and Poupart's ligament. This incision gives access to the entire iliac fossa and vessels. The peritoneum is stripped away, or the peritoneal cavity is entered if desired that it be left on the tumor, or if for individual reasons it seems necessary to explore the peritoneal cavity at this point.

The external iliac vessels are next identified and the artery is securely ligated about 1.5 centimeters below the internal iliac. The leg is then elevated for several minutes in order to recover some of the blood contained in it, following which the vein is ligated. The deep epigastric vessels are ligated and the pubic attachment of the rectus abdominis muscle is divided. The bladder is stripped away from the pubis, the penis is retracted toward the opposite side, and the symphysis is divided either with a knife or by passing a Gigli saw behind it and cutting from within outward. The pubic attachment of the ischiocavernosus muscle is divided close to the bone. Severe bleeding from the periprostatic and periurethral venous plexus may be encountered at this point. Exposure is usually inadequate at this point, and the bleeding is best controlled by sponge packing until the specimen has been removed.

The skin incision is then continued from the posterior superior iliac spine in a downward lateral direction. The flap will be adequate if

the incision is traced over the greater trochanter of the femur and follows the gluteal fold downward medially and forward to meet the anterior incision at the pubic tubercle.

If the gluteus maximus is to be spared, its attachment to the ileum behind the posterior gluteal line is freed. If it is not to be spared, the flap consisting of skin and subcutaneous fat is dissected almost to the sacral midline and the attachment of the gluteus maximus to the sacrum is freed. The extremely tough and short iliolumbar ligament is next cut and also the sacrospinous and sacrotuberous ligaments. The piriformis and levator ani muscles are divided, with the rectum carefully retracted out of the way. The ureter is identified and the iliopsoas muscle is divided. The sacroiliac joint and large posterior nerve trunks are now all that attach the specimen to the patient. These nerve trunks are separated from the bone by blunt finger dissection.

If the largest gluteal muscle is to be spared, care must be exercised at this point in regard to the gluteal vessels which tend to adhere to the bone. Unless they are carefully palpated and stripped off they will be caught in the saw with resultant vigorous bleeding which cannot be controlled until the division of the bone has been completed. The bone being quite broad at this point, it is cut most easily with a Gigli blade passed about it with a long curved clamp. Because the surface of the sacroiliac joint is so irregular, a thin layer of ilium may be cut through. If the tumor is of soft part or femoral origin, this does no harm. However, if the tumor has extended close to the joint, transection is carried through the ala of the sacrum.

The large nerve trunks are simply ligated and divided so that their proximal ends retract well above the level of bone section. Removal of the specimen is now possible and one immediately becomes aware that the remaining wound is not nearly as large as had been imagined. The bleeding, especially about the prostate or urethra, which earlier seemed difficult to control because of its location, is now easily accessible to treatment. Bone wax may be used to control ooze from the sacrum. Drains are placed at each angle of the wound and the edges of the flap are approximated to those of the abdominal wall. A snug pressure dressing is applied.

RESUMPTION OF FUNCTION

It has been our custom to allow an indwelling urinary catheter to remain in place for 48 hours after which voiding has taken place normally. There has been no difficulty with defecation. Final and complete loss of an already flagging ability to sustain an erection occurred in Cases 1 and 2. Case 4 states that she is able to practice intercourse comfortably. Judin's patient bore a child easily and without incident 2 years following the operation.

All our patients have been out of bed from 6 to 10 days after operation and have had no difficulty in learning to sit on one tuberosity. Ambulation must be carried out by the use of crutches.

SKIN FLAP FORMATION

A great deal of attention has been paid in the literature to the type of incision employed. Suffice to say, this should always receive consideration secondary to that given wide surgical removal of the tumor. In general, short flaps, designed to take maximum advantage of the remaining blood supply, applied snugly to the underlying parts, heal the best. Others have found that when no flaps at all are available, secondary grafts may be applied to the extraperitoneal fascia with satisfactory results. The employment of a posterior flap, as first used by Girard, has been in our experience most often applicable. The long medial flaps with some underlying adductor muscle and the preservation of the obturator artery used by Jaboulay offer additional technical obstacles and have, with rare exception, failed. Sparing the adductor attachments and saving the obturator vessels necessitates leaving or removing the innominate bone in fragments. This will sometimes risk incomplete removal or spillage of the tumor.

VESSEL LIGATION

Trite though it may seem, it should be mentioned that vessel ligation should be deferred until the local operability of the case has been definitely confirmed. Although late ligation of the iliacs has been suggested by some, there

would seem to be little point in not ligating major vessels early in a procedure of this size. Frequently the common iliac artery has been ligated offering the advantage of less bleeding posteriorly from parietal branches of the internal iliac. However, in these cases the occurrence of posterior flap necrosis has been fairly common. The optimum point for ligation is, therefore, the upper end of the external iliac artery just below the internal. Temporary atraumatic occlusion of the common iliac or of the internal iliac (after ligation of the external iliac artery) with release after the specimen has been removed, may be done safely if the vessels are not too sclerotic.

MUSCLE

Judin attached considerable importance to saving the gluteus maximus together with its nerves and vessels for later suturing to the abdominal muscles anteriorly in order to better support the abdominal contents. Admittedly, this is occasionally possible without running the hazard of closely approaching tumor tissue and in 1 case we were able to do this satisfactorily. However, in our experience there has been no flap bulge nor have our patients complained of any sensations of weakness when the flap has consisted merely of skin, subcutaneous fat, extraperitoneal fascia, and peritoneum. Reasons for saving the gluteus maximus would therefore seem more hypothetical than real.

Endeavors to spare the attachment of the rectus abdominis muscle also appear to have little justification as their detachment produces so little change.

BONE SECTIONING

In the past a number of factors unrelated to the tumor have often been influential in determining the site for sectioning the innominate bone. Perhaps the most appealing of these was the desire to allow the patient to wear a prosthesis. To fulfill this all or almost all of the ileum was usually left attached to serve as a supporting shelf. In the German literature there are several photographs showing these appliances in place, but it seems likely that they were not very satisfactory when one considers how little is accomplished prosthetically for patients who have had hip joint disarticulations without removal of any of the pelvis.

The wish to retain for the patient the ability to sit has occasionally resulted in sparing the ischial tuberosity and therefore the symphyseal portion of the pubis, but this effort loses force when it is seen how easily these patients balance on one tuberosity even only a few days postoperatively and eventually seem to do as well with one tuberosity as they ever did with two.

Resulting in perhaps the greatest number of incomplete removals of the innominate bone has been a tendency to cut across the sciatic notch, leaving all of the ilium proximal to that point. In most instances this seems to have been prompted by the desire to diminish the extent of the procedure. Such a short cut may be justified for moderate sized tumors of the upper femur but certainly not for large tumors of the pelvic parietes or of the innominate bone itself. Of 22 patients surviving operation whose tumor was definitely stated to involve the innominate bone, 16 were treated by partial removal and only 6 by complete removal of that bone. It is impossible to say because of poor follow-up what actually happened as a result of this, but the necessity for wide removal of osteogenic sarcomas of long bones is so well known that confirmation is hardly necessary here. The innominate bone is a very cancellous structure (Fig. 1) and offers little internal resistance to the spread of tumor. When the tumor lies at either extremity adjacent to the joint it is probable that transection should be made beyond the joint. Pringle hinted at the advisability of this 30 years ago but his suggestions have not been well followed.

The following 6 cases illustrate the varying types of tumor pathology encountered at our hospital:

CASE 1. J. E. D. EFSCH No. 4195. This patient, a 68 year old man, entered the hospital May 5, 1942. About 8 years previous to admission there had been an injury to the right hip and about 1 year prior to entry a lump appeared in the upper portion of the right thigh. This lump became painfully sensitive and gradually increased in size. With the increase in the size of this mass came a limitation of motion with subsequent necessity for a cane. The

right leg became somewhat swollen and the patient lost some weight.

Physical examination revealed a rather poorly developed, pallid male with evidence of recent weight loss. The chest was somewhat emphysematous. The blood pressure was 160/76. Blood count showed a moderate secondary anemia. In the right lower quadrant, there was a hard mass apparently fixed to the ilium and pubis. The regional nodes were not enlarged. There was also a firm mass involving the inner aspect of the right innominate bone. Fullness was present in the femoral triangle, but the femur could be flexed. The prostate was about four times its normal size. An x-ray examination of the chest taken on June 1, showed no evidence of metastases. Roentgenograms revealed a large soft tissue mass in the pelvis overlying the right hip joint and inguinal region. The right femur was in slight abduction. Ill defined curvilinear plaques of calcific density were noted in and about the margins of the tumefaction. There were extensive irregular osteolytic bone changes involving the mesial acetabular aspect of the right iliac bone and horizontal ramus and pubic body. The mesial superior margin of the tumefaction extended obliquely upward from the superior right level margin of the symphysis pubis to the inferior margin of the sacroiliac joint. There was almost complete loss of substance throughout the horizontal ramus and the pubic body. In several areas the osteolytic change had a vacuolated appearance. The mesial rim of the acetabulum was absent and the joint space on that side was narrowed. The articular margin of the head was intact but only the lateral inferior margin of the right obturator foramen remained. More recent osteolytic bone changes were noted in the descending rami on the right. X-ray diagnosis: osteogenic sarcoma (Fig. 2).

Microscopic examination of a biopsy specimen showed a chondrosarcoma. Because of the low blood count the patient was given several preoperative transfusions. A disarticulation of the innominate bone was done on June 19, 1942. Because of the known extension of tumor up to the symphysis, the crura of the penis were detached and bone division was carried 2.5 centimeters to the opposite side (left) of it. In order to resect widely for similar extension to the sacroiliac joint, the right ala of the sacrum was removed. In freeing the pelvic viscera from the medial aspect of the tumor, some adherence to the prostate was noted. Accordingly the capsule and a thin rim of underlying lateral prostatic lobe were removed with the tumor. The gluteus maximus muscle was preserved but in cutting through the sacrum the inferior gluteal artery was inadvertently severed. During closure, however, the entire muscle was thought to be viable. The postoperative course was complicated by severe phantom pains for about 2 weeks. The wound on the tenth postoperative day began to exude serum. A portion was opened and aseptic necrosis of part of the gluteus muscle was seen. After débridement, healing progressed uneventfully and the patient left the hospital August 16, 1942.

Examination of the surgical specimen showed no evidence of involvement of regional lymph nodes or veins. After the femur was disarticulated tumor was found to surround and partially to destroy the acetabulum (Fig. 4). The obturator internus muscle had been largely replaced by tumor. On section, the main tumor mass had obviously replaced muscle and was apparently forming bone. It extended anteriorly and posteriorly to form a huge mass. The space between the synchondrosis and symphysis pubis was filled with tumor although section through the symphysis showed an apparently adequate margin. The tumor had grown up into the ilium, extended out into the ischium, and destroyed the pubis on the right (Fig. 3). The bone marrow of the left pubis at its point of transection was apparently normal and the sacrum showed no evidence of involvement.

Microscopically, this malignant tumor varied considerably in different sections. Neoplastic osteoid tissue and bone were evolving directly from a sarcomatous stroma in several areas. In others, cartilage was undergoing calcification and ossification. In the deeper tissue of the thigh within the muscle, the tumor was very cellular with many mitotic figures and little or no cartilage or bone formation (Fig. 5 a and b). In the region of the acetabulum, cartilage cells with giant and multiple nuclei were observed. The margin of the excision was narrow posteriorly but adequate at the symphysis.

This lesion was classified as an osteogenic sarcoma rather than a chondrosarcoma because neoplastic osteoid tissue and bone were evolving directly from sarcomatous stroma. However, because of the large amount of cartilage and its relatively well differentiated character as a whole, this tumor has a better prognosis than the osteogenic sarcoma which is extremely cellular and vascular. Grossly and microscopically the excision was adequate. At the end of 2 years, the patient was without evidence of local recurrence or distant metastases. A prostatectomy was necessary on December 6, 1943. The prognosis should be good in view of the time that has elapsed since operation (Fig. 6).

Case 2. J. D., EFSCH No. 4981. This patient, a 68 year old man, entered the hospital February 12, 1943. Eight months previous to admission, there had been an injury to the region of the left ischial tuberosity and shortly thereafter a mass formed which slowly but progressively enlarged. During the last month prior to hospitalization, this mass increased in size very rapidly but was never painful nor did it cause any difficulty in walking.

Physical examination revealed a fairly well developed, somewhat undernourished male. There was a huge fusiform mass on the posterior medial aspect

Fig. 1. Innominate bone, sagittally sectioned to demonstrate markedly cancellous nature. Strong argument for complete removal when involved by tumor.

of the upper third of the left thigh extending from the ischial tuberosity to about 15 centimeters above the medial condyle of the femur (Fig. 7). The overlying skin was not adherent to it. In the left groin there was a small tumor measuring 5 centimeters in diameter, thought to be distinct from the main mass.

X-ray examination confirmed the extent of the mass. The underlying bone was normal and the x-ray film of the chest was negative. Aspiration biopsy of the tumor showed an undifferentiated sarcoma. Operation was refused and the patient left the hospital on February 21, 1943. He returned

Fig. 3. Roentgenogram of specimen, Case 1, accentuating the extensive bone destruction.

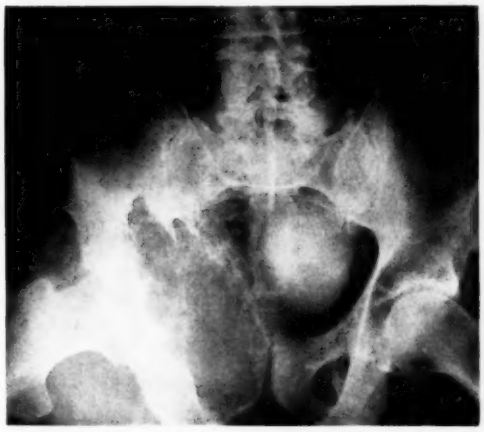


Fig. 2. Case 1. Preoperative roentgenogram. Note marked osteolytic bone changes.

March 11 and the following day a disarticulation of the innominate bone was done.

The tumor mass in the upper thigh had a circumference of 60 centimeters and was not associated with the overlying skin, subcutaneous tissue, tendon sheaths, joint cavities, or nerves. It had stretched the abductor muscle to a convex curve and was intimately associated with the quadriceps extensor muscle of the thigh. On section the mass was fairly well delineated and made up of firm coalescing grey nodules (Fig. 8a). It apparently contained no bone. All regional nodes were enlarged but grossly uninvolved by tumor. There was no evidence of blood vessel invasion. The small mass in the groin was found to be a continuation of the main growth.

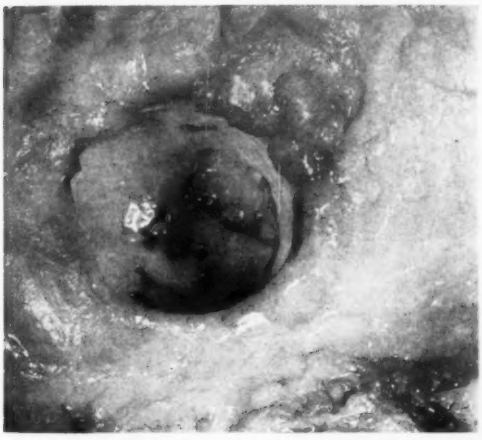
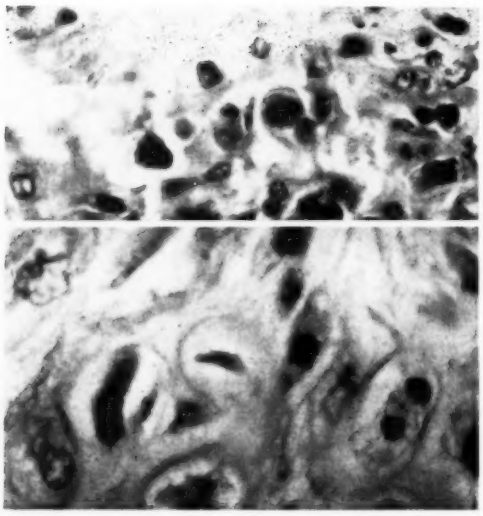


Fig. 4. Note tumor growing around the acetabulum, Case 1.



Figs. 5. a, above, and b, Photomicrographs (high power) from two areas showing the variable histologic picture.

Microscopically the tumor was very cellular, composed of extremely irregular and variable shaped cells which showed numerous mitotic figures. There were many trabeculae of atypical osteoid tissue present (Fig. 8b). The tumor was obviously not primary in the muscle, but appeared to arise from the connective tissue framework. Diagnosis: extraosseous osteogenic sarcoma of the quadriceps extensor muscle (28).

Four months later x-ray examination of the chest was still negative but at the end of 6 months there was evidence of pulmonary metastases and the patient died January 1, 1944. Permission for autopsy was not obtained.

It has been postulated by Leriche and Policard that in the formation of heterotopic bone two things must be present: embryonic fibroblast and an excess of calcium. Butler reported a case in which a metastasizing osteogenic sarcoma developed from a bulky, calcifying hematoma. However, Mallory (22) pointed out through a series of x-ray films in 2 cases that the active phase of metaplasia may occur before the deposition of significant quantities of calcium. X-ray examination of our patient showed no evidence of calcification and multiple sections showed osteoid tissue but no bone. Virchow, Mallory (21), and Leriche and Policard believe that metaplasia of connective tissue can form cartilage and bone, and experimental studies by Asami confirm this observation. This was evidently the mechanism in our case.

Fig. 6. Postoperative photograph of patient, Case 1.

These tumors are extremely rare and most cases reported in the literature have insufficient histologic study and follow-up to be of value (3, 8, 14, 22, 31, 32). Meticulous dissection of the surgical specimen is most important in determining the exact site of origin. There is a question whether trauma might have influenced the genesis of this growth. The prognosis was poor in spite of the technical success of the operative procedure.

Case 3. M. W., EFSCH No. 4999. This patient, a 72 year old man, was first admitted to the hospital on February 17, 1943. Seventeen months before, he noted a growth in the upper portion of the right thigh. This grew rapidly in size, particularly during the last month. There was no history of previous injury, no associated pain or genitourinary symptoms but there had been a 12 pound weight loss in the past 7 months.

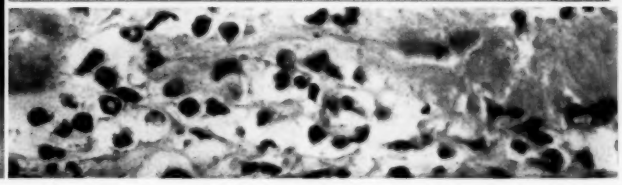


Fig. 7. Case 2. Left, Preoperative photograph demonstrating soft tissue tumefaction.

Fig. 8. a, right, above, Cross section of gross specimen. Note lobulated appearance with sciatic nerve free from evidence of invasion. b, below, Photomicrograph (high power) of tumor. Very cellular with osteoid tissue. Case 2.

Physical examination revealed a well developed, slightly undernourished male who walked with a slight limp, favoring his right side. No masses were felt in the abdomen. In the right groin there was a firm, fairly well fixed mass measuring 17.5 centimeters in diameter and 8 centimeters deep extending from the midinguinal region down approximately to the ischial tuberosity. In the midinguinal region there was a firm lymph node measuring 4.5 by 5.5 centimeters. The urine examination, and alkaline and acid phosphatase were normal.

There was no evidence of metastases in the roentgenograms of the chest, pelvis, or hip joints. In an arteroposterior and lateral view of the proximal portion of the right femur, the pelvis was rotated and a large soft tissue tumor was noted. There was complete destruction of the right pubic body and adjacent portions of the descending and horizontal pubic rami on this side (Fig. 9). There was no evidence of bone production in the region of the soft tissue mass. X-ray diagnosis: primary bone tumor with the characteristics of an osteolytic sarcoma. Intravenous pyelography done on February 24, 1943, was essentially negative.

The lesion of the inguinal lymph node was thought to be a metastatic liposarcoma on biopsy examination. As these tumors are apparently radiosensitive (27), the patient was given intensive radiotherapy between March 1 and May 28, 5 large fields and totalling 15,050r being used. The tumor was reduced to about half its original size. However, because it was persistently present and thought to be a primary liposarcoma of the bone, a disarticulation of the innominate bone was done on June 10. Because of the irradiation, fibrosis was marked and cleavage planes were largely obliterated, greatly adding to the difficulties of the procedure. The patient died 4 hours after operation in irreversible shock.

Gross examination of the surgical specimen showed marked destruction of the rami of the pubis with extension of tumor into the soft tissue and metastases to the inguinal lymph nodes. In the more superficial areas, necrosis and marked radiation effect in the soft tissue and muscle were present, but in the deeper areas, growing luxuriantly in the bone, tumor was present without evidence of radiation. The microscopic diagnosis was a metastatic adenocarcinoma, probably of kidney origin and at autopsy, the upper pole of the right kidney contained a well circumscribed yellow tumor measuring 4 centimeters in diameter (Fig. 10). Although it caused practically no distortion of the renal pelvis, dissection showed invasion of the radicals of the renal vein leading to this area. Metastatic disease had replaced the iliac lymph nodes on the right, but no tumor was present in the lungs or bones.

The differential diagnosis between a liposarcoma and a metastatic adenocarcinoma of bone originating in the kidney is at times difficult, although liposarcomas rarely metasta-

Fig. 9. Case 3. Preoperative roentgenogram. Note complete destruction of right pubic body.

size to the regional lymph nodes. Microscopically they both may reveal large amounts of sudanophilic fat and glycogen. If multiple sections of the metastatic focus are taken and there are no papillary or glandular structures as in our case, the diagnosis is obscure. The primary kidney tumor may be so small, as in this instance, that pyelograms cannot determine the diagnosis. The most important finding in the microscopic appearance is the character of the individual cells. In the renal cell carcinoma, the nuclei are centrally located with well defined outlines and rather foamy vacuolated cytoplasm (Fig. 11a). Liposarcomas, on the other hand, invariably have some cells with eccentric nuclei which are compressed to a crescentic shape by the fat filled cytoplasm (Fig. 11b). The absence of these cells, in this case, plus the involved inguinal lymph nodes should have determined the biopsy diagnosis.

Case 4. F. P., EFSCH No. 3180. Ten months previous to admission on August 2, 1941, this 19 year old married girl first noted a firm painless lump in the left axilla apparently attached to a rib. Four months later, pain developed in the right leg, followed in another month by the appearance of a mass in the right upper thigh. There had been no constitutional symptoms or weight loss and the family history was free of similar disease.

Physical examination revealed a short, small boned but well proportioned female with some deformity and shortening of the left arm. On the chest wall there were several firm masses, apparently attached to ribs. On the lateral surface of the right upper thigh was a large mass with the overlying skin tense but not attached to it. The leg measured 57 centimeters at the point of greatest circumference. The regional lymph nodes were not enlarged.

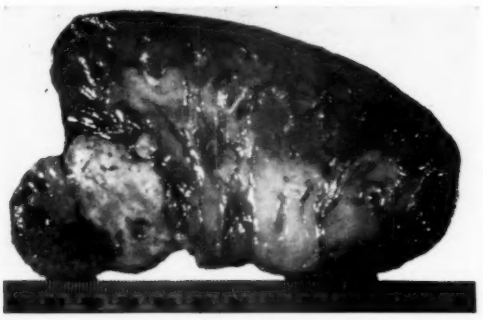


Fig. 10. Gross photograph of kidney showing small, well delineated tumor with little or no distortion of the right pelvis.

X-ray examination revealed a large cartilaginous exostosis arising from the left fourth rib, but no evidence of metastases to the lungs. Smaller exostoses were present in both humeri, radii, and ulnae. There was a lateral luxation of the left radial head with bowing of both radial shafts. Both ulnae were considerably shorter than the radii as the distal ends of both ulnae had failed to develop. Exostoses of the femora, tibiae, fibulae, and pelvis were also present. Occupying the lateral and anterior aspects of the right thigh there was an enormous soft tissue tumefaction extending from above the level of the greater trochanter downward to the midpoint of the shaft (Fig. 12). Throughout this tumefaction, grouped for the most part lateral and anterior to the trochanteric portion of the femur, were numerous blotchy areas of variable shapes and densities. The x-ray diagnosis was multiple cartilaginous exostoses with apparent malignant change in the tumor occupying the region of the right upper thigh.

Routine laboratory examinations were not remarkable. A biopsy specimen taken September 1 showed questionable chondrosarcoma. The patient was seen by several consultants who advised against surgery, not only because of the operative risk but because of the poor prognosis, and the patient left the hospital on September 28.

At each of the subsequent follow-up clinic visits, however, we strongly recommended operation. Roentgenograms showed fairly rapid increase in the size of the tumor, but it was not until August 23, 1943 (about 2 years later), that the patient finally consented to surgery (Fig. 13). She was still in relatively good general condition, although there had been marked weight loss. The tumor now extended from the superior iliac spine to just above

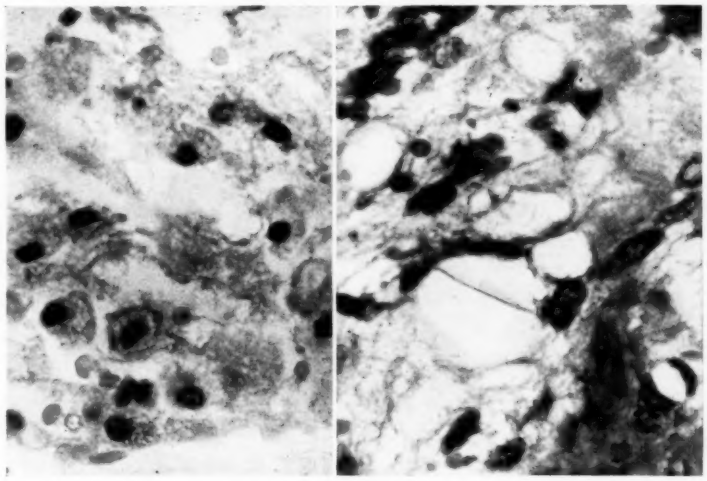


Fig. 11. a, left, Photomicrograph (high power) of carcinoma of the kidney. Note centrally placed nucleus and granular cytoplasm. b, Photomicrograph (high power) of liposarcoma. Note crescentic shaped nucleus and clear cytoplasm.

the patella. The overlying skin was tense and shiny and the circumference of the leg had increased from 57 to 100 centimeters (Figs. 14, 15).

On August 27, a disarticulation of the right innominate bone was performed. No attempt was made to save the gluteus maximus muscle because of posterior encroachment of tumor. The operative and postoperative courses were uneventful, and the patient was discharged from the hospital on the 16th day. The preoperative weight was 106 pounds and the postoperative weight 53 pounds, the specimen representing a loss of one-half the total body weight.

Gross examination showed the tumor growing just beneath the skin but unattached to it (Fig. 16). It extended up to the obturator foramen and was firmly attached to the upper third of the femur. The tumor apparently arose from the cartilaginous cap of the greater trochanter of the femur, but did not invade the femur itself (Figs. 17, 18). It was firm, irregularly cystic with its greatest bulk projecting anteriorly and laterally (Fig. 19a). Numerous large blood vessels coursed over its surface. On section, it cut with increased resistance and small flecks of bone were felt throughout. It was glary light yellow in appearance and the cystic spaces contained sticky, thick fluid. There was no gross evidence of vein or lymph node involvement.

Microscopic examination showed, predominantly, adult cartilage with numerous scattered areas of bone formation. The matrix of the tumor was an intense blue in color. The individual cartilage cells were uniform in appearance and there were no giant forms, or multiple nuclei but rare mitotic figures and plump nuclei were seen (Fig. 19b). The lymph nodes and veins were uninvolved, and the excision apparently was adequate. The microscopic diagnosis was chondroma with probably malignant degeneration.

In 28 cases of multiple exostoses reported by Lichtenstein 3 developed malignant change. He feels that probably the number of cases would have been higher if more time had been allowed to elapse. According to Lichtenstein's histologic criteria, our case should be classified as questionably malignant. However, if one takes into consideration the gross appearance, the clinical course, and the fact that other cases have been known to develop distant metastases, then a diagnosis of chondrosarcoma is justified. The peripheral chondrosarcoma has a much better prognosis than the one arising centrally. It tends to grow slowly, remain localized for a long period of time, recur if inadequately removed and finally to metastasize through the blood stream (23). The metastases are often only extension of the tumor into the large veins and have been known to spread all the way from the femoral vein to the pulmonary artery (17, 30).

This disease has been classified by some as multiple cartilaginous exostoses but is probably best designated as chondrodysplasia. The fundamental cause lies in the proliferation

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 20.

Fig. 21.

Fig. 12. Case 4. Roentgenogram of tumor 2 years before operation.

Fig. 13. Preoperative x-ray film showing tremendous increase of size.

Fig. 14. Case 4. Preoperative photograph of patient (front view).

Fig. 15. Preoperative photograph of patient (side view).

Fig. 16. Surgical specimen. After removal patient's weight dropped from 106 to 53 pounds.

Fig. 17. X-ray film of specimen.

Fig. 18. Photograph of the gross specimen showing probable site of origin of the malignant tumor.

Fig. 19. a, left, Gross specimen, cross section. Note the cystic spaces which are responsible for blotchy areas in the roentgenogram. b, Photomicrograph (high power) of tumor showing fairly adult cartilage. Case 4.

Fig. 20. One year postoperative photograph of patient (front view).

Fig. 21. One year postoperative photograph of patient (side view).

Fig. 16.

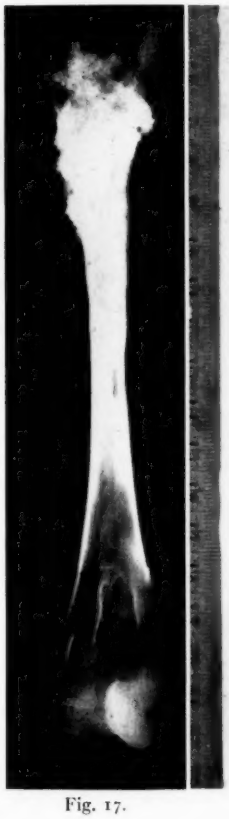
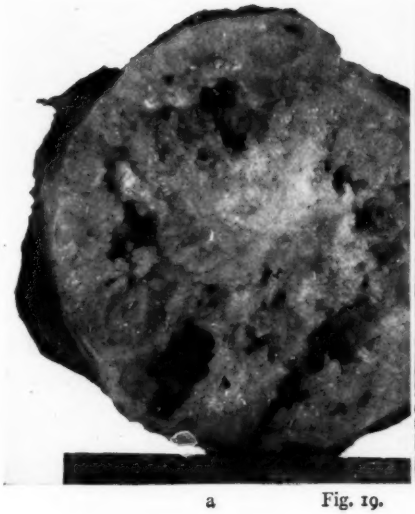


Fig. 17.

Fig. 18.



a

Fig. 19.

b

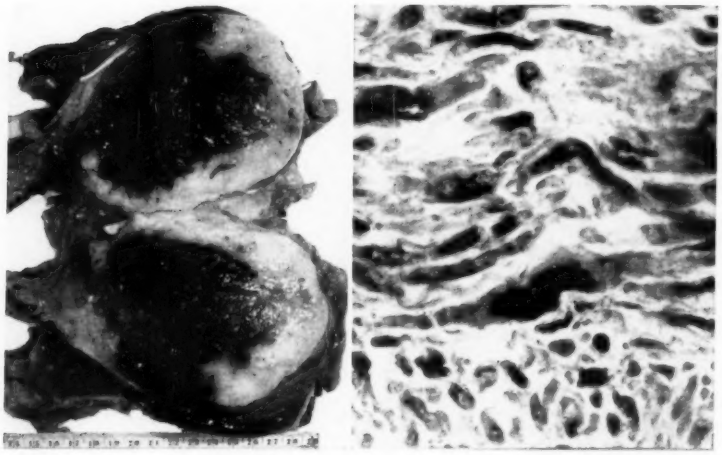


Fig. 22. Case 5. a, left, Gross photograph of tumor demonstrating central hemorrhage and peripheral cellular tumor. b, Photomicrograph (high power). Note giant tumor cell.

and ossification of bone-forming cartilage. It is hereditary in nature, the proliferation and ossification of intermediate cartilage occurring during the period of skeletal growth (6, 7, 16).

This patient has gained 30 pounds since operation, is in excellent general health and is able to use her crutches very well (Figs. 20, 21). A prostheses may be made. In view of the pathology and wide excision the prognosis appears excellent, although it is possible that malignant changes may develop in one of the other lesions.

Fig. 23. Postoperative x-ray film.

CASE 5. W. H. L., EFSCH No. 6281. The patient, a 58 year old male, was admitted to the hospital on April 21, 1944. Pain in the right groin, partially relieved by flexion of the thigh on the hip was first noticed 6 weeks before. There was also increasingly severe pain radiating down the posterior surface of the thigh causing discomfort in flexion. There was no history of trauma, previous treatment, or weight loss.

Physical examination revealed a well developed, well nourished male whose right thigh was flexed at the hip. There was marked muscle guarding in the right iliac fossa and a large firm mass, questionably attached to the ilium, could be felt.

Barium enema revealed an extrinsic pressure defect of the cecum at the level of the iliac crest. Intravenous pyelography showed mesial displacement of the right mid-ureter. The chest plate was negative. Aspiration biopsy of the mass showed an unclassified sarcoma.

As there was no evidence of distant metastases, an exploratory operation was done. The incision began just above the posterior superior spine of the right ilium and curved inferiorly and medially parallel to the crest of the ilium down across Poupart's ligament, and the peritoneum was opened anteriorly above the mass. No abnormalities of the abdominal contents were noted. A large rubbery mass occupying the upper portion of the wing of the ilium and extending on up along the psoas almost even with the attachments to the transverse processes of the lumbar vertebra was present retroperitoneally. Medially, the mass extended nearly to the lower lumbar vertebra. Several large vessels

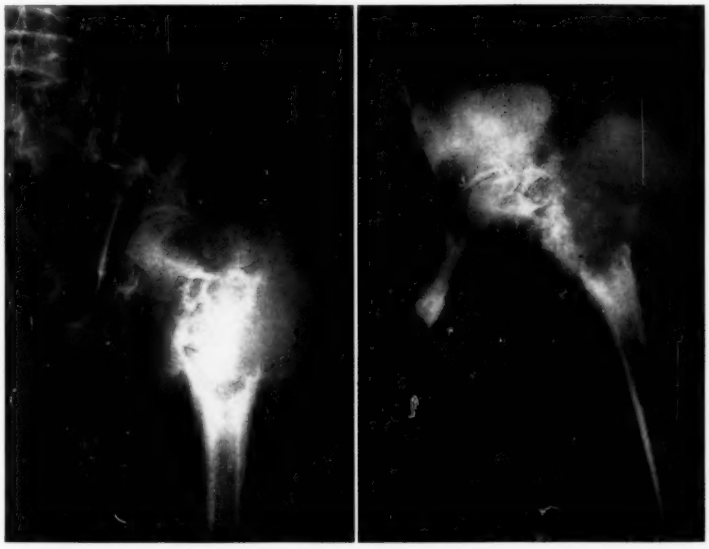


Fig. 24. Case 6. Left, Preoperative x-ray film showing tumor and area of fracture.
Fig. 25. X-ray film of specimen.

entered it. The peritoneum medial to the mass was incised and resutured to the peritoneum anteriorly thus closing the cavity leaving undisturbed the peritoneum directly overlying the mass. The external iliac vessels were partially surrounded but not infiltrated by tumor. Although the right ureter was displaced, it appeared to be uninvolved. Anything short of wide radical removal would doubtless result in a recurrence around the external iliac vessels and, accordingly, a disarticulation of the innominate bone was carried out. The specimen consisted of the right hind quarter. The symphysis pubis had been divided in the midline and the scrotum just medial to the iliac joint. There was a rounded, soft, somewhat cystic mass measuring 15 by 10 by 10 centimeters incorporated in the psoas muscles but lying for the most part in the iliac fossa extending 5 centimeters above it. The psoas muscle was thinned out and surrounded the tumor mass. On section, actual bone involvement was absent. The tumor was soft yellowish gray in color and areas of hemorrhage were present. It apparently arose from the iliopsoas muscle (Fig. 22a). The nodes showed no gross evidence of tumor.

Microscopically the tumor was undifferentiated and showed apparent transition from muscle. Cross striations could not be definitely demonstrated but they are often not present. There were many mitotic figures and bizarre giant forms present (Fig. 22b); Rakov states these large cells are always seen in undifferentiated form of rhabdomyosarcoma.

The postoperative course was uneventful for 16 days (Fig. 23) when the patient complained of some lower right chest pain. There was no hemoptysis and roentgenogram of the chest was not remarkable though the symptoms suggested a small pulmonary embolus. The patient died suddenly the next day with symptoms corresponding to a large pulmonary embolus. Permission for postmortem examination was not granted.

The location of this tumor, the gross appearance, apparent origin from muscle and the microscopic findings all substantiated the diagnosis of rhabdomyosarcoma. If the patient had recovered from the operation, pulmonary metastases or local recurrences would probably have developed within a year.

CASE 6. J. G., EFSCH No. 7018. A 55 year old male was admitted to the hospital on December 2, 1944. Four years before the patient suffered severe trauma to the left thigh. The site of injury was painful for several days, but there were no further symptoms until November, 1943, when a dull, aching persistent pain, not exaggerated with motility started in the upper portion of the left hip. In May, 1944, he turned his left leg with a cracking sound, fell to the ground unable to move the leg and was taken to a local hospital. Shortly thereafter a large mass developed in the left thigh and he was referred to this hospital for treatment.

Physical examination showed a well developed, fairly well nourished male. In the left upper thigh there was a fusiform mass measuring 65 centimeters

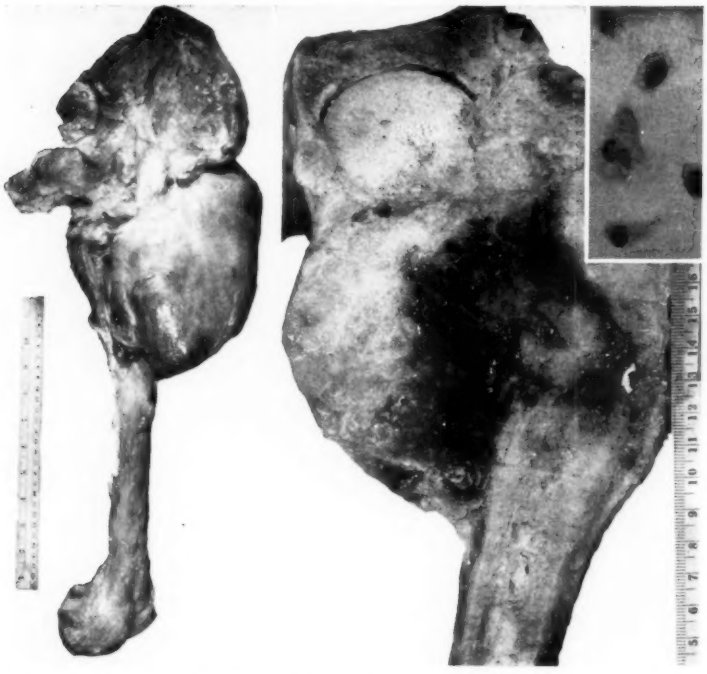


Fig. 26, left. Gross photograph of specimen.

Fig. 27. a, right, Gross photograph of specimen on cut section, demonstrating area of hemorrhage, gelatinous character of tumor, zone of fracture, and extension of tumor into medullary cavity. b, above, Photomicrograph (high power) demonstrating plump and multiple nuclei.

in its greatest circumference. The skin was tense and shiny but moved smoothly over the firm, underlying suggestively cystic mass. A few superficial veins were present.

Laboratory examinations showed only slight secondary anemia. The acid and alkaline phosphatase were normal. X-ray examination showed a destructive bone lesion with a fracture of the neck of the left femur (Fig. 24). There was a large soft tissue mass of varying densities in this area. Roentgenogram of the chest showed no evidence of metastases.

Several preoperative transfusions were given and on December 4 a disarticulation of the left innominate bone was performed without incident. The postoperative course was uneventful except for aseptic sterile necrosis of approximately 2 square inches of the flap.

Pathological examination showed a large tumor replacing the upper third of the femur (Figs. 25 and 26). It extended out into the soft tissue across the bone fracture and continued downward into the upper third of the medullary portion of the shaft (Fig. 27a). The tumor was quite soft, mucoid, partially cystic, and contained small pieces of bone. There was no gross involvement of veins, regional lymph nodes or acetabulum. The surrounding muscles showed partial replacement.

Microscopic examination showed no evidence of vein invasion or lymph node metastases. The tumor was cartilaginous, the individual cartilage cells often having plump nuclei, multiple nuclei, and mitotic figures (Fig. 27b). The stroma surrounding the tumor consisted of fairly adult connective tissue showing no evidence of sarcomatous change. A few spicules of bone were present.

This tumor grew slowly for at least 1 year and examination showed apparent complete removal. Because it was a chondrosarcoma, probably arising centrally, there should be a good prognosis, although the possibility of vein invasion (although not found histologically) is always possible. This again shows the importance of the pathological pattern in determining the ultimate prognosis.

RECAPITULATION

As a life-saving measure, transection through or above the innominate bone appears to be a very effective procedure in handling sarcomas of the pelvic parietes and upper thigh. The mortality rate of 14 per cent for the past 10 years as compared with 56 per cent for the preceding 40 years is very encouraging. That only 99 operations of this sort have been reported during a 50 year period is clear indication, however, that only a very few of these cases are being given the benefit of radical surgical removal. A glance at the tables in the book by Geschickter and Copeland confirms this, since none of their patients was treated in this manner.

A comparison of our own experience with that of others would indicate that a disproportionately large number of younger patients have been selected for operation. Of the 93 cases reported, exclusive of our own, only 11 were over the age of 50 and only 2 were over 60. Since Fitzwilliams' case represents the only one (besides the authors') over 60 years surviving operation, there might have been some justification for such selection in the past. It should be recalled, however, that a high percentage of osteolytic sarcomas of bone, in which the prognosis is extremely poor, will be found among the younger group. With the decrease in operative mortality it would seem reasonable to select patients in the future less on the basis of age and more on the basis of the pathology of the tumor.

It is apparent that the benign tumors such as the neurofibromas, benign giant cell tumors, giant osteochondromas, and chondromas may be expected to present the best prognosis. The next most favorable group will be the chondrosarcomas arising either peripherally or centrally. The peripheral group arising usually from cartilaginous exostoses will offer the better outlook. Well differentiated soft tissue sarcomas of long duration should be operated upon, although the prognosis will be less favorable. Osteogenic sarcomas forming large amounts of adult cartilage (Case 1) should certainly have the benefit of operation. This is also true of osteolytic osteogenic sarcomas and very undifferentiated soft tissue sarcomas, although among these the salvage will be very low. Ewing's sarcomas, plasma cell myelomas, and metastatic tumors, if recognized as such, should probably not be subjected to such an operation except under unusual circumstances.

Examination of the surviving patients reveals that in certain instances even more radical treatment is necessary if the results are to be improved. There is no known surgical means of coping with subclinical metastases, and many patients presenting these tumors will undoubtedly die of distant spread subsequent to resection, as is already known to be true of histologically similar tumors situated peripherally in sites amenable to the commoner types of amputation. On the other hand, it is frequently within the surgeon's means to prevent local recurrence as it is a well known tendency for many of these sarcomas, unless widely removed, to recur stubbornly. Obviously one of the distinct advantages of operations of this sort for tumors in the upper thigh and lower pelvis is the wide removal permitted. Yet of 45 patients followed, 8 developed stump recurrences: The first case, a chondrosarcoma of the lower innominate bone, with incomplete section above, had a recurrence 17 months after operation. The second case had a chondrosarcoma of the ileum, with section through the notch, and there was a recurrence in 5½ years. In the third case, a chondrosarcoma of the ileum, the gluteus maximus was preserved; recurrence 1 month later. In the fourth case a chondrosarcoma of the ileum, there was a recurrence in 2½ years. In the fifth case, an osteochondrosarcoma of the acetabular region, section was through the notch; recurrence 12 months later. In the sixth case, a myxochondrosarcoma of the upper femur, an effort was made to save the adductor muscles; recurrence 6 months later. In the seventh case, a benign recurrent chondroma of the ileum, there was recurrence 4 years after operation. In the eighth case, a spindle cell sarcoma of the upper thigh, section was through the sciatic notch; recurrence 5 months later. Probably not all of these were avoidable, but it is significant that in 4 of these the innominate bone was incompletely removed although it represented the site of involvement in 3. In 1 instance the

gluteus maximus muscle was preserved when the tumor was situated in the adjacent and attached ilium. In still another case with tumor in the upper femur, attention was focused on the preservation of a long medial skin flap with the underlying adductor thigh muscles and the obturator artery. Six of these 8 recurring cases were chondromatous tumors of bone and 2 were soft part spindle cell tumors. In our first case, in recognition of the tendency which bone sarcomas have for crossing joints, the entire innominate bone was removed together with a generous segment of the opposite pubis as well as the ala of the sacrum. In Case 4 the gluteus maximus muscle was removed in order to maintain an additional zone of safety between the disease and the line of section. Both of these patients remain well. Experience to date, therefore, indicates that fuller advantage of the procedure should be taken in making it as radical as the tumor demands and the anatomy permits. It is firmly believed that when this is done the end-results will be considerably improved.

SUMMARY

1. Fifty years have elapsed since Girard first successfully resected a portion of the pelvis along with the lower extremity for a sarcoma of the upper femur which would not lend itself to disarticulation at the hip joint.

2. Similar procedures have now been reported for malignant tumors of the upper femur, innominate bone, and adjacent soft parts in 99 patients.

3. Although an overall mortality of 28 per cent exists, that of the first 40 year period was 56 per cent but during the past 10 years it has dropped to 14 per cent. This drop has been largely due to development in the treatment of shock, which has been the primary complication of this operation.

4. Follow-up data, although woefully inadequate, indicates that of 45 patients surviving operation and followed for from 1 to 5 or more years, 21 remained clinically well and 24 died of their disease.

5. The deformity, although considerable, is borne gratefully by these patients who have usually become convinced that there remains no hope of cure.

6. The anatomy, operative procedure, and variations in technique are discussed.

7. Six unselected cases are given, all with at least a removal of entire innominate bone.

8. In criticism of the past treatment it may be said: that far too few patients have received the benefit of radical operation; that the advantages of wide resection have not been sufficiently exploited, particularly as regards partial or incomplete removal of the innominate bone when that bone itself represents the site of the tumor; that with more adequate control of the mortality, patients be selected less on the basis of age and more on the basis of the pathology of the tumor. It is believed that consideration of these factors in the future will favorably influence the prognosis in sarcomas of the upper thigh and pelvic parietes.

REFERENCES

1. Asami, G., and Dock, W. J. Exp. M., 1920, 32: 745.
2. Billroth, T. Cited by Savariaud, W. (26).
3. Butler, F. E., and Woolley, I. M. Radiology, 1936, 26: 236.
4. Cacciopoli, G. Riforma med., 1894, 10 (pt. 2): 819.
5. Cooper, W. G., Zumwalt, W., and Sugarbaker, E. D. Surgery, 1944, 16: 886.
6. Ehrenfried, A. J. Am. M. Ass., 1915, 64: 1642.
7. Idem. J. Am. M. Ass., 1917, 68: 502.
8. Ferrero, V. Arch. ital. chir., 1925, 12: 236.
9. Fitzwilliams, D. C. L. Proc. R. Soc. M., Lond., 1938, 31: 548.
10. Geschickter, C. F., and Copeland, M. M. Tumors of Bone. New York: Am. J. Cancer, 1931.
11. Girard, C. Rev. chir., Par., 1898, 18: 1141.
12. Gordon-Taylor, G., and Wiles, P. Brit. J. Surg., 1935, 22: 671.
13. Jaboulay, M. Lyon med., 1894, 75: 507.
14. Jaidka, M. C. Brit. M. J., 1919, 2: 379.
15. Judin, S. S. Surg. Gyn. Obst., 1926, 43: 668.
16. Keith, A. J. Anat., Lond., 1919, 54: 101.
17. Kosa, M. von. Virchows Arch., 1929, 272: 166.
18. Leighton, W. E. Arch. Surg., 1942, 45: 913.
19. Leriche, R., and Policard, A. Les Problemes de la Physiologie Normale et Pathologique de l'Os. Paris: Masson et Cie, 1926.
20. Lichtenstein, L., and Jaffe, H. L. Am. J. Path., 1943, 19: 553.
21. Mallory, F. B. The Principles of Pathologic Histology. P. 276. Philadelphia: W. B. Saunders Co., 1914.
22. Mallory, T. B. Am. J. Path, 1933, 9: 765.
23. Phemister, D. B. Surg. Gyn. Obst., 1930, 50: 216.
24. Pringle, J. H. Brit. J. Surg., 1916, 4: 283.
25. Rakov, A. I. Am. J. Cancer, 1937, 30: 455.
26. Savariaud, W. Rev. chir., Par., 1902, 26: 350.
27. Stewart, F. W. Am. J. Path., 1931, 7: 87.
28. Stout, A. P. Personal communication.
29. Virchow, R. Virchows Arch., 1884, 97: 410.
30. Warren, S. Am. J. Path., 1931, 7: 161.
31. Williams, E. R. Brit. J. Radiol., 1934, 7: 45.
32. Wilson, H. Ann. Surg., 1941, 113: 95.

PARACHUTE FRACTURES

PAUL A. KNEPPER, F.A.C.S., Major, M.C., St. Joseph, Missouri

A SURVEY of fractures which occurred in a regiment of paratroop infantry during a 6 month period of intensive training is presented. The injuries sustained in jump training at Fort Benning have been covered by Tobin (2), Lord (1), and Tobin (3). The altitude of the area over which jumps reported in the present study were made is approximately 4,000 feet, in marked contrast to the training area at Fort Benning, Georgia, 300 feet above sea level.

The over-all incidence of casualties was as high as 10 per cent in some of the jumps at the beginning of training. A casualty was defined as absence of soldier from duty for 24 hours or longer. The number of accidents was rapidly reduced until at the end of the period of training, the casualty rate was less than 1 per cent.

The optimum speed of the airplane during release of parachutists is about 100 miles per hour for a static line jump. The pilots had difficulty slowing to that speed in the C-47 Transport at the beginning of training, owing to the relatively low density of the atmosphere over the training area. (Mean barometric pressure about 650 millimeters of mercury against 760 millimeters at sea level). The jumps were made at 800 feet above ground level in the beginning of training, gradually dropping to 600 feet as the program went on.

The impact at which the parachutist hits the ground is equal to that of a fall from a height of 10 to 15 feet. If the ground is at an altitude of 4,000 feet, the impact is equal to that of a fall from 15 to 20 feet.

A wind of over 12 to 15 miles per hour greatly increases the number of casualties. In the area where these jumps are made, the standard saying is "If you do not like the wind or weather, wait 30 minutes and it will change." Consequently, jumps were occasionally made in wind velocities as high as 35 to 40 miles per hour. In practice maneuvers with other airborne troops, the jumps had to be made as scheduled, thus causing some jumps to be made during inclement weather.

Psychoneuroses, including hysterical states and malingering, were very uncommon in paratroopers. Practically no cases were seen in officers. A few occurred in enlisted men toward the end of training when the outfit was very "hot." Most of these were traumatic neuroses involving back pain following a jump and were completely refractory to treatment of any kind, physical or psychiatric.

Back injuries were not common. There were 7 cases of compression fractures of the vertebrae. None was complicated by paralysis. There was not a single case of protruded intervertebral disc found during this period of training. Back sprains of any severity were uncommon as the men were taught to land on their feet and roll forward. The 7 cases of compression fracture were all associated with one of two complications; the primary "chute" did not open and the secondary "chute" was used, or another parachutist accidently emptied part of the air from the "chute" which carried the man who was injured. There were no compound fractures and no fatal accidents.

The head injuries included two (2) linear fractures and four (4) of the basilar type. These injuries all happened in a high wind which caused the parachutist to land sideways, striking the head in some manner. All recovered, but 2 of them were permanently removed from "jump status" because of post-traumatic symptoms. Encephalograms revealed no evidence of gross damage to the brain. I am unable to state if they were instances of traumatic neurosis or permanent cerebral damage. None of the patients was subjected to surgery.

Acromioclavicular separations were not common. Injuries to the acromioclavicular joint were treated by depression of the clavicle and immobilization. Separation of the conoid and trapezoid ligaments was repaired by open operation. The technique of Bunnell, using fascia lata, was employed. There were 4 of these cases. Satisfactory result was obtained and all returned to jumping after 4 months.

Fig. 1, left. Fracture of the posterior lip of the right tibia.
Fig. 2. Same fracture as in Figure 1, but 30 days later, showing healing of posterior lip fracture.

Fig. 3, left. Fracture of posterior lip of tibia without displacement.
Fig. 4. Incomplete healing, 35 days later.

Following is a list of the types and numbers of fractures: skull, 6; nose, 4; maxilla, 2; humerus, 5; radius, 4; navicular (carpal), 3; metacarpals, 6; phalanx, 7; rib, 4; compression of vertebrae, 7; sacrum, 1; coccyx, 1; femur, 1; patella, 2; tibia, 22; trimalleolar, 6; fibula, distal portion, 29; astragalus, 1; os calcis, 3; cuboid, 2; tarsal, 2; metatarsal, 7; toes, 4; a total of lower extremities of 79 and a grand total of 129.

Fracture of the posterior lip of the tibia is so typical a parachute injury that it has been named "paratrooper fracture" by Tobin (3). This fracture is uncommon other than in parachute injuries and for that reason has received a small amount of attention in the literature of traumatic surgery.

Parachutists are taught to land on the ball of the foot. This is possible if there is no wind and the terrain is even, but too often this is not the situation. These fractures occur when the weight of the body is transmitted through one foot instead of being divided. The excellent type of boot worn by the parachutist prevents the fracture from being more frequent, because it distributes the transmitted force through the lower leg.

The anatomy of the ankle joint further explains the fracture. The posterior lip of the tibia is lower than the anterior so that the joint mortise is wider anteriorly than posteriorly. The external and internal malleoli keep the astragalus in line and a transmitted force must shear off the posterior lip preferentially. The posterior one-fourth of the joint

Fig. 5. Excess callus in case of patient treated elsewhere and not immobilized. Patient had painful, swollen ankle joint.

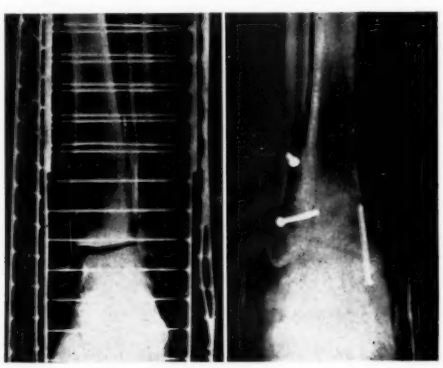


Fig. 6, left. Severe trimalleolar fracture of ankle with tearing of tibiofibular ligament.
Fig. 7. Anteroposterior view showing internal malleolus fixed with screw and fibula fixed with tibia with screw. Joint space normal.

surface is most commonly involved. Separation of fragments is rare. Open operation has never been necessary in my experience in fracture of posterior lip from parachute injury.

This history is typical: the parachutist lands on one foot in uneven terrain or due to oscillations from a high wind, with immediate pain in the ankle joint and great difficulty in walking. In all such fractures which occurred at this Station, not one was missed in the field. By this, I mean they were sent into the hospital immediately and demonstrated by lateral x-ray films. This justifies the term "paratrooper fracture" because it is so often diagnosed accurately by field medical units.

A method of treatment was established which I would like to describe in detail: (1) A padded plaster cast is applied from the base of the toes to the tibial tuberosity. (2) The foot is placed in the neutral position. (No inversion or eversion, i.e., a line through patella would go between great toe and second toe). (3) The ankle is placed in exactly 90 degrees dorsiflexion. (4) An anesthetic may be necessary to get the ankle in proper position. (5) The patient is kept on absolute bed rest for 1 week, with elevation of the extremity on two pillows. (6) After 1 week, the cast is removed and replaced by another cast with a very small amount of padding. A section of wool felt 2 by 2 inches is placed dorsally over the tarsal bones. (7) After 48 hours, the patient is allowed to walk on the leg. No crutches or walking calipers are employed. The cast will frequently break on the bottom, but good support is given to the ankle nevertheless. (8) The cast is removed after 2 weeks and daily whirlpool baths of 30 minutes in the morning and infra-red treatment for 1 hour in the afternoon are given. One week of this treatment will suffice ordinarily and the parachutist is ready for full duty, including marches. There will be no circulatory changes in soft tissue or bone, no swelling of the ankle at night and no restriction of motion.

CASE 1. Patient was injured in a parachute jump when he landed with his entire weight on his right foot. There was immediate pain, swelling, and disability of the right ankle. Physical examination showed a marked swelling of the ankle (Figs. 1, 2). A circular plaster cast was applied with foot in neutral position and ankle at 90°. The foot was kept 30 days in cast; and patient was 37 days in hospital.

CASE 2. Patient was injured in a parachute jump when his right ankle got caught in the suspension lines in landing so that his body was twisted with his ankle remaining stationary. There was immediate pain, swelling, and inability to walk on the right foot. Physical examination showed severe swelling of the right ankle. Circular plaster cast was applied with a walking iron. (Figs. 3, 4). Leg in cast 30 days; patient in hospital 49 days.

CASE 3. Patient was injured 2 months before admission "elsewhere" when he became entangled with another "chute" in landing and injured his left ankle. He was treated as an out patient, but his ankle remained swollen and painful (Fig. 5). A plaster cast was applied for 30 days. Total time in the hospital was 40 days; poor result.

CASE 4. Patient was injured in a parachute jump in a high wind when he landed entirely on his left foot and twisted in falling. There was immediate pain, swelling, and inability to walk on the left ankle. Physical examination showed marked swelling of the left ankle (Figs. 6, 7). Open operation with a screw in internal malleolus; one through fibula into tibia to allow tibiofibular ligament to unite. Leg in cast 40 days; patient in hospital 51 days, on convalescent furlough 21 days, a total of 72 days away from duty.

Case 1 shows the ideal result when the aforementioned routine is carried out.

Case 2 demonstrates an increased length of time when the ankle is not immobilized at exactly 90 degrees.

Case 3 shows the permanent disability that may occur in an ankle if the fracture is not recognized primarily and properly treated.

Case 4 shows a severe type of fracture and the good result obtained from open operation.

CONCLUSION

1. A review of the number and type of fractures encountered in parachute training of a regiment at a relatively high altitude is presented with a brief discussion of the causes of such injuries.

2. Typical case histories of "paratrooper fracture" are outlined.

3. A detailed method of treatment of "paratrooper fracture" is given.

REFERENCES

1. LORD, C. DONALD, and COUTTS, JAMES W. J. Bone Surg., 1944, 26: 547.
2. TOBIN, W. J., CICONE, R., VANDOVER, J. T., and WHOL, C. W. Army M. Bull., 1943, No. 66, p. 202.
3. TOBIN, W. J., COHEN, L. J., and VANDOVER, J. T. J. Am. M. Ass., 1941, 117: 1318–1321.

WOUNDS OF THE RECTUM

C. NAUNTON MORGAN, M.B., B.S. (Lond.), F.R.C.S. (Eng.), Brigadier, R.A.M.C., London, England

WOUNDS of the rectum are serious because of their inaccessibility, the risk of spread of infection in the buttocks and connective tissue planes, and often the difficulty of diagnosis. The frequent association of injury to other structures, especially the bladder and large blood vessels, or extensive comminution of the sacrum, ischium, or pubis, with subsequent osteomyelitis, adds greatly to the gravity of wounds in this region. The immediate mortality is high, and, since many of these wounds are quickly fatal, comparatively few, compared with wounds of the small or large intestine, are seen at the base.

Wounds of the rectum may be extraperitoneal, intraperitoneal, or combined. Combined wounds are those in which the intraperitoneal portion of the rectum is injured from below or the side, thus involving the extraperitoneal tissues, and, in addition, those extraperitoneal wounds of the rectum associated with penetration of the pelvic cavity. Intraperitoneal and combined wounds were not seen so frequently in the survivors arriving at the Base, so it is likely that they are more fatal than extraperitoneal wounds. The increased hazard of peritonitis, the difficulty of approach to a tear low in the depth of the pelvis, and associated abdominal injuries in the rectovesical pouch, are among the explanations.

The diagnosis of a wound of the extraperitoneal portion of the rectum may easily be missed, especially when there is an apparently trivial wound of entry in the thigh. Though, in the series of wounds analyzed, there are several extraperitoneal injuries which were not treated by colostomy for several days and yet patients survived, in general the spread of infection in the extensive deeply-seated tissue planes is a serious matter. Damage to the thick, coarse muscle of the gluteal regions also favors the development of gas gangrene. Although no complete figures of its frequency are yet available, "colon septicemia" (acute fulminating infection), described by Sir John Fraser in the 1914–1918 war, still takes its toll. At least 3 of the deaths in this series appear to have been due to a fulminating bloodstream infection.

The wound of entry is usually in the buttocks, sacral region, perineum, or hips. Missiles traversing the pelvic girdle from the side usually produce widespread damage to bone, bladder, and urethra. Occasionally, a missile entering the abdomen from the front and above will injure the rectum.

Several instances of the bursting type of injury of the perineum with retraction upward of the anorectal region and isolation of the anus from the perianal skin have been seen. The explanation suggested by Sir Charles Gordon-Watson that this type of injury occurs as the result of the disrupting effect of the missile in the loose connective tissue while the pelvic musculature and sphincters are tightly contracted, like the "bursting of a paper bag," is probably correct.

Extensive perirectal trauma without penetration of the bowel must be treated promptly on the same lines as is penetration owing to the diffuse extravasation of blood with spread of infection in the loose connective tissue of the pelvis with secondary involvement of the rectal wall. Infection from wounds of the buttocks, with or without fracture of the sacrum, may extend through the fascia propria and spread upward in the extraperitoneal plane. Occasionally a missile may lie between the rectum and sacrum.

The following case illustrates the danger of pelvic cellulitis following a severe buttock wound without penetration of the rectum.

An Italian P.O.W., wounded 6 days previously, arrived at the Base in a very poor condition; there was an extensive and heavily infected gaping wound of both buttocks with a large shell fragment lying in the subcutaneous tissues. He complained of lower abdominal pain and the abdomen was found to be

Consultant Surgeon, Persia/Iraq Force. Assistant Director, Surgical Unit, and Assistant Surgeon, St. Bartholomew's Hospital, London, Senior Assistant Surgeon, St. Mark's Hospital, London.
Submitted for publication in June, 1944.

rigid and tender in its lower half. On examination of the rectum, its wall was very edematous and thickened, but there was no evidence of any breach of its surface. Exploratory laparotomy revealed pelvic peritonitis with an enormously swollen, turgid, and inflamed rectum and sigmoid colon standing rigidly upright and filling the pelvis. The retroperitoneal tissues, mesorectum, and colon were blood stained, very edematous, and inflamed with a gangrenous area in the mesorectum, to which a coil of small intestine was adherent. Sulfathiazole powder was sprinkled into the pelvis and a left inguinal colostomy was performed. The coccyx was then removed, and, by division of the fascia propria, the perirectal tissues were drained. There was no demonstrable continuity between the buttock wounds and the pelvis, and no fracture of the sacrum had occurred. Intravenous sulfapyridine and sulfonamide by mouth were given and recovery followed a stormy convalescence.

DIAGNOSIS

Injury to the rectum may easily be overlooked because the evidence of its involvement may at first be very slight. In 21 extraperitoneal penetrating wounds in this series, 7 were not diagnosed until feces and flatus were passed through the wound of entry.

Wounds of the buttock involving the anorectal region are usually obvious, though the exact state of affairs cannot be assessed until the patient is examined under an anesthetic. Damage to the urethra may complicate wounds of this portion of the rectum.

Extensive comminution of the sacrum strongly suggests the possibility of rectal damage, while passage of blood per rectum, palpation of a tear, presence of blood on the examining finger or of feces in the wound will establish the diagnosis. A steady stream of blood from the entry or exit wound usually indicates serious injury.

In extraperitoneal lesions of the rectum, extravasation of blood and inflammatory products into the extraperitoneal planes of the abdominal wall may produce, after some hours abdominal tenderness and rigidity suggesting an intraperitoneal complication.

Intraperitoneal damage to the rectum is most commonly diagnosed as the result of signs of peritoneal involvement—suprapubic tenderness and rigidity. The frequency of intra-abdominal injury with small penetrating wounds of the buttocks is common knowledge; careful observation and examination of the abdomen in such cases are essential. Reconstruction of the event, the position of the soldier when wounded, the type and trajectory of the missile, will help the surgeon in his decision. With a penetrating wound, an x-ray examination is of great importance and should be carried out when possible.

A catheter must be passed in all cases with wounds of the pelvis and perineum to exclude damage to the bladder or urethra. The possibility of injury to the sciatic nerve or cauda equina should also be remembered.

TREATMENT

Chemotherapy, both local and general, during and after operation, is of great value in wounds within the pelvis. With extensive damage and soiling, it is wise to administer intravenous sulfa drugs, especially sulfadiazine.

A colostomy should always be established in all cases of penetration of the rectum, when rectal injury is suspected, or there is extensive extravasation in the pelvic connective tissue planes. A temporary colostomy often makes the nursing and control of infection of a large buttock wound, especially when adjacent to the anus, much easier.

Extraperitoneal wounds. The entrance and exit wounds are first trimmed, then explored and enlarged for drainage. The extent and position of the rectal tear may be judged and the likelihood of intraperitoneal damage considered. A wound of the extraperitoneal portion of the rectum should not be sutured.

If the lesion in the rectum is high near the peritoneal flexion, the pelvis must be inspected through a midline abdominal incision, but if intraperitoneal damage is unlikely, a "blind" left iliac colostomy may be performed and a swab on a holder inserted through the colostomy incision into the pelvis to exclude the presence of blood, etc.

Drainage of the extrarectal tissues should be established under the following conditions: extensive laceration of the rectum, widespread extraperitoneal hematoma, excessive bleeding from the subperitoneal pelvis, and established retroperitoneal infection. The pelvic cellular tissue is difficult to drain, but, by excision of the coccyx, division of the fascia propria, and

opening up of the perirectal space by finger dissection, the best possible drainage is acquired. To avoid turning the patient, the lithotomy position with a sandbag under the sacrum should be used for excision of the coccyx. A wound near the lateral border of the sacrum may be extended vertically along the side of the coccyx and sacrum; good access to the perirectal connective tissue plane is thus obtained.

There is never need to destroy the sphincter mechanism by division of the anorectal musculature, but dilatation of the anus and the insertion of a large tube at the end of the operation will aid drainage.

During convalescence, if the perirectal space has not been drained and there are signs of spread of infection, no time should be lost in opening up this area.

With bursting or explosive injuries, because of the time lag, extensive soiling, etc., it is usually unwise to attempt reposition of the retracted bowel. When this has been done, sutures have usually cut out, and, what is more serious, drainage has been inadequate; sepsis is kept up by pocketing under skin flaps, etc. In one such case, the patient improved only after pocketing under bridges of skin and extension of sepsis into the buttocks were treated by laying open widely the whole area. The speed with which the perianal wound healed and the patient improved was astonishing. The anal canal will function normally whatever its position if its nerve and muscle control has been preserved. Wide excision of the perianal musculature is usually unnecessary and should be avoided.

Foreign bodies encroaching on the sacral canal should be treated with conservatism and caution, since there is a definite risk of meningitis. One such patient arrived at the Base with established meningitis which responded to sulfapyridine; the metallic foreign body was removed 4 weeks later, the patient having sulfapyridine before and after operation. In this series, removal of a foreign body on the 8th day was followed, 10 days later, by death from meningitis.

Intraperitoneal wounds. When an abdominal lesion has been diagnosed, exploration of the entry or exit wound should be deferred until the abdomen has been opened and the pelvis examined. It may be possible to suture an intraperitoneal tear, or, if this cannot be done, the damaged area may be shut off from the general peritoneal cavity by means of the omentum or a Coffey drain. A catheter is placed down to the site of injury, a colostomy established, and the abdomen closed. A suspension of 10 grams of sulfadiazine in 50 cubic centimeters of a solution of gelatine and saline (3% gelatine in normal saline) is injected down the catheter. The wounds of entry, exit or both are then trimmed and enlarged for drainage; turning the patient should be avoided if possible. The wicks of the Coffey drain are removed piecemeal after the 3d day.

Colostomy. The most desirable site for a colostomy is as near the rectal lesion as possible, i.e. a sigmoid colostomy with a good spur. If a plastic repair operation is considered likely in the future, it is best to leave a good loop of colon below the temporary colostomy. In cases of urgency, the colostomy may be performed through the exploratory incision. For an extensive wound of the pelvirectal region with a short sigmoid loop, a transverse colostomy will make future operation on this portion of the gut easier. It must always be remembered, however, that the prime object of the operation is to save life.

Repair of rectal perforations. This problem will not be faced, as a rule, for several months after wounding. Continued infection, especially from osteomyelitis, will prevent plastic operation, but it is important during this waiting period always to assure free drainage and complete exclusion of the rectum by means of a satisfactory colostomy.

Unless there has been extensive tearing of the gut, intraperitoneal wounds will probably finally close themselves; the difficult cases are those extraperitoneal wounds high in the rectum under cover of the sacrum, especially with a fistula passing through the bone. The internal opening of these fistulas is usually obscured by a shelf of mucosa, and the rectal wall is firmly adherent to the sacrum.

Daily injection into the distal loop of the colostomy of a freshly made 20 per cent suspension of sulfasuxidine in water (*p*H 7) is useful in controlling infection.

Penicillin will undoubtedly help in the closure of these fistulas. In the case of one patient with a large tear in the posterior wall of the lower third of the rectum, early repair was attempted, followed by the use of penicillin locally.

6404302 Cpl. B.R. had a perforating mortar wound of the back and buttock. Operation was done 14 hours after wounding—entry wound just to left of third lumbar vertebra, exit wound left buttock. A large rectal tear was palpable on digital examination of the rectum. Toilet of wounds—left inguinal colostomy—no intra-abdominal contamination. Postoperative treatment consisted of administration of antigas gangrene serum and a full course of sulfonamide. Continuous intravenous glucose saline was also administered.

He arrived at the Base 3 weeks later in good condition. There was a small healing entry wound in the left lumbar region and some fullness of the left buttock with an exit wound discharging thin pus. Crepitation could be felt under the skin. There was diminished sensation in the sole of the left foot with diminution of the ankle jerk, and x-ray examination showed comminution of the left side of the 2d, 3d, and 4th pieces of the sacrum, involving the foramina. The lower colostomy loop was washed through daily with 1:1000 flavine, but operation was necessary for treatment of the sacral osteomyelitis.

Operation was done 26 days after wounding. The buttock wound, which led to bare bone, was considerably enlarged, and the track of the missile was laid open by dividing the attachment of the gluteus maximus from the coccyx and last two pieces of the sacrum; the coccyx was excised. There was a hole over 1½ inches long and about ¾ inch wide in the left side of the posterior rectal wall. The rectum together with its fascia propria was mobilized sufficiently, and, after the edges of the rectal defect were freshened, this was closed by an inverting suture reinforced by Lembert sutures in the fascia. A catheter was placed in front of the sacrum up to the sacral fracture site and the skin was completely sutured apart from an exit for the catheter in the lower part of the buttock. The wound was irrigated three times daily with 500 units of Florey's penicillin through the catheter.

The suture line in the rectum broke down partially, and pus discharged from the rectum and colostomy; the patient's general condition was excellent, and the skin healed soundly—he now had a "blind" internal fistula. Two months after operation, drainage for osteomyelitis of the sacrum and sequestrectomy were necessary. Fifteen days later there was a tiny superficial wound over the sacrum which was healing rapidly.

Penicillin had made possible, even in the presence of osteomyelitis of the sacrum, the conversion of a large, external rectal fistula into a small one of the "blind" internal type.

ANALYSIS OF CASES

In a series of 32 penetrating wounds of the rectum, there were 26 extraperitoneal lesions and 6 intraperitoneal or combined. Since most of these patients were seen at the Base, it seems that either intraperitoneal injury is less common, or, more likely, extraperitoneal damage to the rectum is less dangerous. Rapidly fatal acute infection occurred in both types of wound.

Extraperitoneal Wounds

Of the group of 26 extraperitoneal wounds, there were 5 of the *anorectal region* complicating wounds of the buttock or perineum. In 3 the anorectal area was torn, while in 2 the injury was mainly of the bursting type of injury of the perineum with retraction of the anal canal. The 3 patients with avulsion of the anorectal region were treated by colostomy and drainage. In 2 the colostomy had been postponed for 3 days; 1 of these died of gross infection of the wound. The 2 bursting injuries were also treated by colostomy and by reposition and suture of the retracted anus. In both cases the sutures gave way, though in 1 case the right side of the anus remained in position. During convalescence, the provision of free drainage necessitated wide division of the skin and the laying open of all subsidiary pockets in 1 case. In 3 of the 5 cases, fracture of the bony pelvis (ischium, pubis, and coccyx) complicated the anorectal wounds and in 1 case the extrapelvic urethra was injured.

There were 21 *wounds of the rectum* and the site of entry was as follows: buttock, 11; sacrum, 7; groin, 1; hips, 1; buttock and groin, 1. The diagnosis of injury of the rectum was not made in 7 cases (one-third) until feces or flatus were passed through the entry wound 4 to 6 days after the wounds were received. In 1 case with associated bladder injury, the poor condition of the patient suggested injury to the rectum on the second day. Five of the 7 undiagnosed cases were treated by late colostomy. Two died, 1 with associated bladder injury, the other from meningitis following removal of a foreign body from the sacral canal, on the 8th day.

Injury to the rectum was diagnosed in the remaining 14 cases (two-thirds) as follows:

blood per rectum on examining finger, 2; extensive sacral wounds with fracture, 2; feces in the entry wound, 2; tear palpable, 2; blood per rectum and palpable tear, 1; tear visible, 1; exploratory laparotomy—marked extraperitoneal hemorrhage spreading into mesosigmoid, 1; no record, 3.

The time lag in the cases of wounds of the rectum was recorded in only 11 of the diagnosed cases: within 12 hours, there were 5 cases and of these 1 died of hemorrhage and shock and 3 of fulminating infection; within 12 to 24 hours, there were 5 cases and all recovered but 1 was traced for only 7 days and 1 other died from infection 7 weeks later; within 29 hours, there was 1 case and he recovered. Two of the 5 cases in which operation was done within 12 hours had severe injuries and were not expected to recover. The number of cases (including the undiagnosed) that recovered in spite of a long time lag is surprising. Even though these injuries may kill quickly from fulminating infection, a number of patients recovered even without early colostomy.

Of these 21 cases with wounds of the rectum, 14 were associated with fractures (two-thirds) as follows: fracture of the sacrum, 6; fracture of the ischium, 4; fracture of the pubis, 2; fracture of the coccyx, 1; fracture of the ilium, 1. In 2 of these cases the femur was fractured in addition and in 1 the fracture extended into the hip joint.

Other organs were affected as follows: bladder, 2, of which 1 died; urethra, 1 who died; cauda equina, 1 who recovered.

In the cases which were diagnosed, treatment consisted of colostomy with or without abdominal exploration; the wounds were trimmed and enlarged for drainage. Though in these cases there is no definite information available of the use of local or general chemotherapy, its use was routine. Antigas gangrene serum was also used in a few cases.

Intraperitoneal and Combined Wounds

There were 6 cases in this group. The site of entry wounds was as follows: buttock, 3; sacrum, 2; perineum, 1. As to diagnosis, all had signs of intra-abdominal injury, but in 2 cases only was there any indication of a rectal lesion before laparotomy—1 with blood on the examining finger and the other had a large sacral wound.

The time lag was 8 to 16 hours except in 1 case in which the lag was 24 hours and in another 36 hours. One patient with a time lag of 8 hours and another of 36 hours died of acute infection. The 16 hour case in which patient recovered, passed a large Ascaris lumbricoides on the 16th day! In the 24 hour case, patient had an extraperitoneal lesion of the rectum, and, though the rectovesical pouch was full of blood, no intraperitoneal lesion was found. This patient had several secondary hemorrhages from the wound, rectum, and colostomy, requiring ligature of the superior gluteal and finally the internal iliac artery.

Other injuries found in this group were fracture of the sacrum in 2 cases and injury of the small gut in 4 cases.

All patients in this group were treated by exploratory laparotomy, colostomy, and drainage. In 3 cases the intraperitoneal rectal tear was sutured and all recovered; in 2 cases suture of the intraperitoneal tear was impossible and both died; in 1 case the rectal lesion was extraperitoneal and patient recovered. Local sulfa drugs were used except in the 36 hour case with general peritonitis and for the extraperitoneal injury of the rectum.

Nonpenetrating Wounds of the Rectum

There were 6 cases in this group. In 3 cases abdominal tenderness and rigidity suggested intraperitoneal damage, and exploratory laparotomy was performed. In all these cases there was extensive retroperitoneal hemorrhage in the pelvis with peritonitis, though in 2 there was no evidence of penetration of the peritoneal cavity; the small gut was injured in the third case. The time lag in the 2 cases exhibiting abdominal signs without penetration of the pelvic cavity was 1 and 6 days. Colostomy was established in all cases. In the fourth case exploratory laparotomy was performed because an extensive sacral fracture indicated an injury to the rectum; a colostomy was made as there was present a large retroperitoneal hematoma. In the remaining 2 cases colostomy was not performed. The

foreign body was removed from the pararectal tissues in 1; in the other a small foreign body could be felt through the rectal wall. This patient complained of pain in the perineum, especially on defecation; pressure on the foreign body produced pain in the distribution of the 3d, 4th, and 5th left sacral nerves. A small granulomatous nodule in the region of the foreign body was visible on sigmoidoscopy.

Complications

During convalescence, it is important to maintain adequate drainage constantly. Osteomyelitis not infrequently follows injury to the bony pelvis, and pocketing and tracking of pus occur. Large wounds of the sacrum are difficult to nurse and are subject to prolonged infection with its concomitant risks. Meningitis following lodgement of foreign bodies in sacral canal has already been mentioned; after considerable time, preliminary sulfonamide therapy and gentleness in removing such foreign bodies are essential. Only when a foreign body here requires removal should it be operated upon. Diphtheritic infection of the sacral wound was seen in 1 case. Secondary hemorrhage complicated 3 cases—rather a higher incidence than with wounds of the extremities.

Deaths

In the extraperitoneal rectal wounds, there were 8 deaths. Two occurred within 24 hours, 1 from a fulminating infection and 1 from hemorrhage and shock. The death from fulminating infection (colon septicemia) occurred in a soldier who was operated upon 12 hours after wounding. His wounds were severe, including a fractured femur and a torn urethra and injury to the small gut in the rectovesical pouch. He died of profound toxemia with a terminal temperature of 108 degrees. One died within 48 hours from a fulminating infection (colon septicemia). He was operated upon 12 hours after wounding. The abdomen was distended but there was no peritonitis. One died within 5 days. Operation was performed 8 hours after wounding. There was extensive retroperitoneal bruising. He became jaundiced after blood transfusion but death was most likely due to severe infection. Two died within 14 to 21 days: 1 on the 16th day from gas infection of the abdominal wall and thighs and secondary hemorrhage; one on the 18th day from meningitis following the removal of a foreign body (time lag 8 days). Two died after 1 month: in 1, death occurred in 48 days from infection following injury to both bladder and rectum with a rectovesical fistula. The rectal injury was not diagnosed and colostomy was performed late. In the other case, death occurred in 49 days from an anaerobic streptococcal infection associated with fracture of the sacrum and neck of the femur; chemotherapy and repeated blood transfusion were of no avail.

There was 1 death in the anorectal wound group. Death occurred in 10 days from extensive infection of the perineum and buttocks together with bronchopneumonia. Colostomy had not been performed until the 3d day.

There were 2 deaths among the intraperitoneal wounds. Both occurred within 6 days: In 1 from an unsutured tear of the rectum treated after a 36 hour time lag by drainage and colostomy. Patient was jaundiced before death and had peritonitis and toxemia. In the other, from an unsutured tear of the rectum treated after an 8 hour time lag by drainage and colostomy. Patient had acute toxemia but no evidence of peritonitis.

In the nonpenetrating wounds, 1 patient died from a wound which involved the thigh, and the pelvis was fractured; anaerobic streptococcal infection and osteomyelitis developed and death followed in 2½ months.

In the last world war a small series of wounds of the rectum, complicated by wounds of the small intestine, showed a mortality rate of 100 per cent, while in the Middle East in this war a small series of similar wounds showed a mortality of 71.4 per cent (Ogilvie). In this paper, since there is no information available of all the deaths from wounds of the rectum in the Forward Units, a mortality figure cannot be given. However, compared with the last war, the number of survivors suggests an improvement in results.

SUMMARY

1. The classification and diagnosis of wounds of the rectum are discussed.

2. Operative treatment of extraperitoneal, intraperitoneal, and combined wounds is de-

scribed. The indications for drainage of the pelvic cellular tissues are given.

3. The risk of spread of infection within the pelvis with nonpenetrating wounds is mentioned.

4. Thirty-two penetrating and 6 nonpenetrating wounds of the rectum are analyzed:

a. Among the penetrating injuries there were 26 extraperitoneal and 6 intraperitoneal or combined wounds.

b. Early diagnosis was made in only two-thirds of the extraperitoneal wounds; the methods of diagnosis are shown. Signs of intra-abdominal injury were present in all cases of intraperitoneal or combined wounds.

c. The incidence of various sites of entry wounds, of fractures of the pelvis, and of other injuries is given.

d. The time lag, complications and deaths are considered.

REFERENCES

1. Fraser, Sir John. Brit. M. J., 1917, 1: 321.
2. Gordon-Watson, Sir Charles. Surgery of Modern Warfare. 3d ed., Sect. xviii, Chap. lxxvii. Edited by Hamilton Bailey. Baltimore: The Williams and Wilkins Co., 1944.
3. Ogilvie, W. H. O. Surg. Gyn. Obst., 1944, 78: 225.
4. Pulvertaft, R. J. V. Personal communication.

CONCUSSION OF THE SPINAL CORD

An Experimental Study and a Critique of the Use of the Term

R. A. GROAT, Ph.D., W. A. RAMBACH, JR., B. S., and W. F. WINDLE, Ph. D.,
Chicago, Illinois

THE meaning of the term, concussion of the spinal cord, is sufficiently vague to be a source of irritation to those who wish to use it. The present investigation was undertaken because it was felt that experimental clarification of functional and morphological aspects of an uncomplicated injury to the spinal cord, the type which rightfully deserves to be called concussion, was needed to aid in restricting the sphere of application of the term. Studies in brain concussion (13, 14, 42) provided a background for the present experiments.

As will be described in the present report, uncomplicated concussion of the spinal cord in the cat is a complete functional block of the spinal cord at the level of application of an adequate force to the nervous parenchyma. Nerve cells, especially of interneurons, and long ascending and descending fiber tracts are involved. The period of concussion is brief, passing into the period of postconcussion when the paralysis ceases. Subtle but histologically demonstrable cell alterations occur in concussion, and frank chromatolysis is evident in postconcussion as a direct result of the injury sustained. In any species, if some other morphological change is present, e.g., compression fracture, self-reducing fracture dislocation, severe epidural or subdural bleeding, contusion or laceration of the spinal cord or spinal nerve roots or intramedullary hemorrhage, which superimposes functional alterations upon those of concussion, the injury is not concussion but concussion plus the complicating injury.

MATERIAL AND METHODS

Concussion was produced in cats by striking a single blow against the back of a freely suspended animal with a blunt wood instrument swung in a horizontal plane. Chalk applied to the instrument enabled accurate determination of the site of the blow. Most of the animals were lightly anesthetized with chloralosane. Others were struck after the spinal cord had been transected at the midthoracic level under ether, and the region of the operation anesthetized with procaine. The blow was strong enough to produce a brief paraplegia when applied over the lumbar enlargement in intact, unanesthetized cats.

In all animals the saphenous branch of the femoral nerve was exposed on the thigh and a unipolar or a bipolar stimulating electrode was attached to it. In 3 cats a fine bipolar stimulating electrode was placed in one pyramidal tract in the pons with the Horsley-Clarke instrument. The stimulator[1] employed was one which gave a reversed saw-tooth wave, and the voltage, frequency, and the falling phase of the stimulus were controlable. Output dials were calibrated to show peak voltage.

The threshold voltages for elicitation of the appropriate responses were recorded over a 10-minute period immediately preceding a blow. Uncomplicated concussion was deemed to have occurred when the threshold rose instantaneously following a blow and then returned uneventfully to the control level. Blows were applied over various regions of the spinal cord. In two of the cats receiving midthoracic blows, the vagus nerves were cut at the start of the experiment. Observations of functional alterations were made in 27 cats. Seven were allowed to live for 6 days, 3 for 14 days and 1 indefinitely after the concussion; the rest were killed at the end of the threshold-testing period. All except the 14 day animals, which were used for Marchi degeneration studies, were perfused with 10 per cent formalin[2] (following initial washing out of blood with 0.9 per cent NaCl) while under nembutal anesthesia and were then autopsied.

Ten of the formalin-perfused animals furnished histological material. For additional histological material 3 cats were arranged for perfusion before being struck. The start of flow of formalin was timed so that fixing fluid entered the animal's body approximately 5 seconds after the blow was

From the Institute of Neurology, Northwestern University Medical School.

The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Northwestern University.

[1] Designed by Dr. Craig Goodwin and similar to that described by Dusser de Barenne, Garol, and McCulloch (9).

[2] Some were perfused with a formalin, acacia, sodium chloride solution according to a new method (24).

struck. Three cats, anesthetized, surgically prepared, and electrically stimulated but not struck, served to control the histological phase of the work. Preparation of the spinal cord material and staining of the Nissl bodies, myelin sheaths, and axis cylinders were carried out as described in a previous paper on brain concussion (42). Some cords were sectioned transversely; others, longitudinally in the coronal plane. Serial sections were obtained from spaced regions of the entire cord.

The method for staining the Nissl material of the nerve cell cytoplasm was designed to give great uniformity of results. It employs dilute solutions of thionin made up in buffers of pH 4 to pH 4.5. Staining is carried progressively to completion and decolorizing is unnecessary. Control and experimental material of the present study was stained together simultaneously.

In order to facilitate the interpretation of cell changes which occurred in the spinal cords of the experimental animals, ventral roots were sectioned intradurally in 5 other cats and the animals were sacrified 6, 12, and 18 days after operation. Two or three roots were cut in each animal and the series embraced the third lumbar to the first sacral inclusive on one side only. Control material was afforded by the intact side of the cord and by portions of the adjacent segments cranial and caudal to those corresponding to the sectioned roots. The animals were fixed by perfusion with formalin, acacia, sodium chloride solution (24). The appropriate portion of the spinal cords was serially sectioned longitudinally in the coronal plane and the sections were stained by the method for Nissl bodies (42).

PHYSIOLOGICAL RESULTS

Stimulation of the saphenous branch of the femoral nerve elicited reflex contraction of muscles supplied by the sciatic nerve. A distinct foot movement was chosen as the response for observation. A blow applied over approximately the sixth lumbar spinal cord segment produced concussion, the severity of which was ascertained by the magnitude of increase and the duration of recovery time of the threshold for the femoral-sciatic reflex. The severity of the concussion increased with the strength of the blow. The longitudinal extent of spinal cord involved in concussion upon a given blow also depended upon the strength of that blow. A blow producing concussion at the seventh and eighth thoracic segments did not spread sufficiently to produce concussion of the region of the cord involved in the femoral-sciatic reflex, i.e., fifth lumbar to second sacral. It resulted in hyperirritability of the hind quarters to saphenous nerve stimulation. Blows spaced from the eleventh thoracic down to the third lumbar segments caused progressively greater increase in threshold for the femoral-sciatic reflex. Effectiveness of blows over the first and second caudal vertebrae in producing concussion of the region of the lumbar enlargement was much reduced.

In the few times observed, a femoral-obturator reflex behaved just as the femoral-sciatic reflex.

Contraction of the platysma muscle below the mandible also resulted from stimulation of the saphenous nerve. A blow producing concussion at the lumbar enlargement caused a rise in threshold of this femoral-facial reflex. A blow producing concussion at the seventh and eighth thoracic segments did the same.

Stimulation was applied in the pyramid to evoke hind limb movement and slight forelimb movement. A blow at the lumbar enlargement caused a rise of threshold for hind limb movement. A blow at the seventh thoracic segment likewise readily caused an increase, although forelimb movement, motor nerves for which originate from cord segments closer to the site of the blow, was little affected.

Occasionally an animal exhibited considerable general muscular activity on saphenous stimulation. A blow at the lumbar enlargement completely abolished this response while one at the level of the seventh thoracic segment extinguished it only rostral to the level of the blow.

In one-fourth of the instances in which concussion was produced at the level of the lumbar enlargement, the hind limbs immediately extended in tonic spasm lasting 5 to 25 seconds. The occurrence of spasm seemed to be unrelated to the severity of concussion.

Results from animals with vagus nerves or spinal cord sectioned did not differ from those described above.

In stimulating the saphenous nerve a wave frequency of one per second and nearly always a falling phase of 20 sigma were used. Control threshold values (values recorded before concussion) for the femoral-sciatic and femoral-facial reflexes ranged from 0.1 to 0.4 volt. Concussional thresholds extended to greater than 10 volts. Stronger stimuli were not used. In two-thirds of the instances, thresholds returned to the control values. In the rest, thresholds returned nearly to control levels. Recovery was generally accomplished in 1 to 5 minutes although the time ranged from less than 1 to 15 minutes. In general, thresholds fell gradually through the recovery period, usually faster during the early part.

For stimulation in the pyramid, a frequency of 100 per second was employed. Control thresholds ranged from 2.0 to 5.0 volts. Other details were the same as those described in connection with saphenous stimulation.

No gross functional aberrations referable to spinal cord damage were seen in the injured cats in a period of 14 days after the concussion. There is the possibility, however, that the proper type of test would reveal some abnormalities.

MORPHOLOGICAL RESULTS

Most of the animals which were struck one blow suffered no hemorrhage inside the vertebral canal although many had traces of blood in the musculature at the site of the blow. Some had light extradural or subdural hemorrhage but no intramedullary bleeding. In these and in two cats which suffered complete transverse fractures of intervertebral discs without any alteration inside the vertebral canal there were no functional indications of the complicating condition. A second or third hard blow at the same level often produced intramedullary hemorrhages or extensive subdural bleeding leading to compression of the cord. Delayed effects of these complicating injuries upon thresholds could usually be observed in such cases. In 2 instances very strong blows produced fractures which lacerated the cord and produced functional results readily distinguishable from those of concussion.

Histological examination of the affected region of the spinal cord of the animals perfused immediately after the blow revealed subtle changes among all nerve cells except the motoneurons. The Nissl bodies of most neurons seemed to be agglutinated and the nucleolus was more often irregular as compared to control material and as compared to more remote segments in the same animal. These changes were essentially the same as reported in the brains of guinea pigs upon concussion (42).

The chief histological alteration found in the spinal cord 6 days after concussion was chromatolysis of nerve cells at a level underlying the external site of the blow. The principal participants in this reaction were interneurons of large and intermediate size of both dorsal and ventral grey columns. Many were reduced to mere shadows, which could not be photographed, although all stages of degeneration were found; some may be seen in Figures 4 to 8. The smallest interneurons were probably also affected, perhaps even diminished in number, but it is difficult properly to assess changes in these small cells.

The longitudinal spread of this process of chromatolysis and the number of cells affected by it were directly proportional to the severity of the concussion. Following a moderate concussion many chromatolyzed cells were found within about a 3 centimeter length of cord. For a distance of about 1 centimeter beyond either end of this region were found a relatively few scattered cells undergoing chromatolysis.

A comparison of the concussion material with spinal cords from animals in which ventral roots had been sectioned intradurally revealed two pertinent points. First, relatively few motoneurons (cells which underwent chromatolysis following severance of ventral roots) underwent chromatolysis after concussion and these were located within a few millimeters of the center of the affected length of spinal cord. Second, most of those chromatolyzed motoneurons found 6 days after concussion were in a stage of degeneration far beyond that of motoneurons 6 days (or even 12 or 18 days) after ventral root section. Compare Figure 2 with 3.

The only axis cylinder abnormalities seen in the spinal cord 6 days after concussion were some terminal bulbous enlargements. These occurred only in the more severe concussions, and then, to what would seem to be an insignificant extent. They were nearly entirely limited to the lateral funiculi in a segment of cord 3 or 4 millimeters long at the middle of the injured region. The absolute extent of this pathology was 10 millimeters to 15 millimeters.

Myelin sheaths, as studied with the Weil stain, were normal. So were blood vessels. There was no proliferation of glia or transformation into pathological glia in the injured regions. Dorsal root ganglia, dorsal roots and ventral roots showed no abnormalities 6 days after concussion, even at the level of most intense chromatolysis within the spinal cord.

One cat was allowed to live indefinitely after sustaining three spinal cord concussions, one of which was severe. The animal remained healthy, continued to grow, and showed no abnormalities. At last observation, 7 months after the injuries were inflicted, the cat weighed 4.12 kilograms as against the original weight of 2.95 kilograms. Thus, spinal cord concussion was not followed by slowly progressive degeneration in the spinal cord due to primary nervous tissue damage or to vascular involvement.

DISCUSSION

It would seem that one important facet of spinal cord concussion is interruption of function of the cell bodies of the interneurons and, to a much less extent, of the lower motor neurons. Certainly

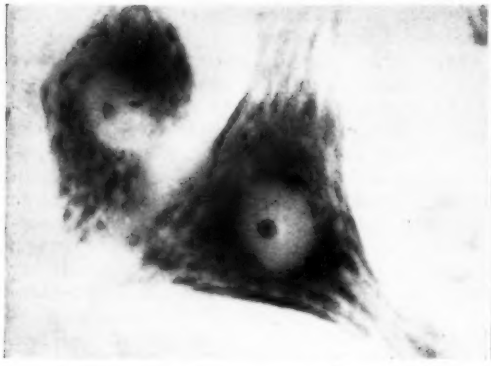


Fig. 1, left. Normal motoneurons in the seventh lumbar segment of the spinal cord of a cat. × 575.

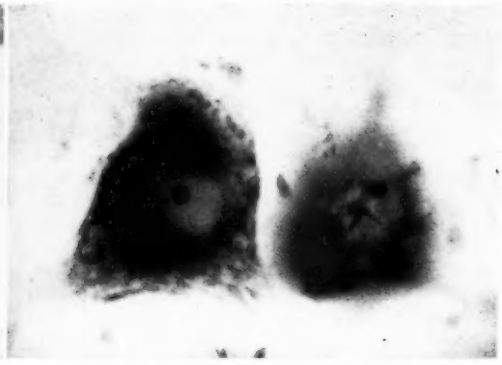


Fig. 2. Incipient chromatolysis of motoneurons in the seventh lumbar segment of the spinal cord of a cat 6 days after intradural section of the corresponding ventral root The cell at the right is out of focus. × 575.

it is the interneurons which show the principal histological alterations in spinal cord concussion and postconcussion and it is the interneuron cells which bear the brunt of the functional and histological changes in brain concussion. A blow over the lumbar enlargement abolishes the motor response of the hind limb to a stimulus applied to the pyramidal tract in the pons. This is more likely due to paralysis of interneurons on which pyramidal tract fibers end (27) than to paralysis of the motoneurons themselves. We recall that in brain concussion the excitability of the cranial motor nuclei was usually not at all, or but little, decreased while reflexes involving those nuclei were nonelicitable (13). Since in brain concussion the fibers were not blocked, the seat of these reflex disturbances seems to have been the interneuron cells.

The present experiments demonstrate that one element of concussion of the spinal cord is a block of long ascending and descending nerve fibers. This is different from brain concussion, in which the functional integrity of nerve fibers is little, if any, affected (13). The discrepancy is probably rooted in a difference in the mechanical features involved in concussion of the two parts of the central nervous system. Whether or not short nerve fibers and the extremities of long nerve fibers are blocked in spinal cord concussion is unknown.

Of interest are the observations that some degree of tetanus of hind limbs occurred in only one-fourth of the concussions of the region of the lumbar enlargement and that tetanus did not occur

Fig. 3, left. Chromatolysis of a motoneuron in the fifth lumbar segment of the spinal cord of a cat 6 days after concussion of the spinal cord. × 575.

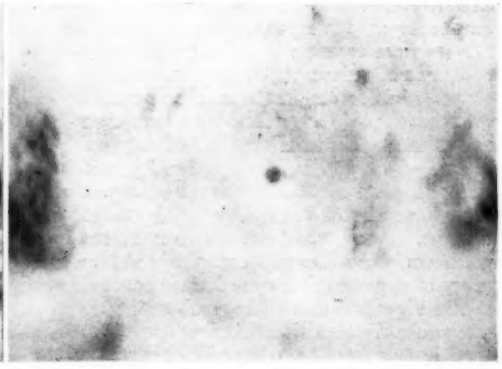


Fig. 4. Chromatolysis of a large interneuron in dorsal part of ventral gray column in third lumbar segment of spinal cord of a cat 6 days after concussion of spinal cord. ×575.

Fig. 5.

Fig. 5. Chromatolysis of a large interneuron in the dorsal part of the dorsal gray column in the fifth lumbar segment of the spinal cord of a cat 6 days after concussion of the spinal cord. × 610.

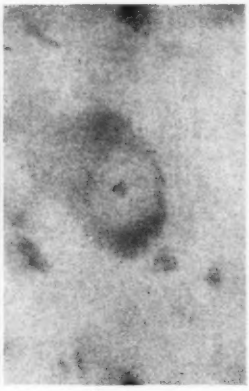


Fig. 6.

Fig. 6. Chromatolysis of a medium size interneuron in the ventral part of the dorsal gray column in the fourth lumbar segment of the spinal cord of a cat 6 days after concussion of the spinal cord. × 610.

Fig. 7.

Fig. 7. Chromatolysis of a medium-small size interneuron in the ventral part of the dorsal gray column in the fourth lumbar segment of the spinal cord of a cat 6 days after concussion of the spinal cord. There is a normal interneuron above the chromatolyzed cell. × 610.

Fig. 8.

Fig. 8. Chromatolysis of a small interneuron in ventral part of dorsal gray column in fourth lumbar segment of spinal cord of a cat 6 days after concussion of spinal cord. ×610.

in any concussions of the midthoracic region. If the conduction block in nerve fibers which we demonstrated was analogous to that which Krems, Schoepfle and Erlanger observed in the dissected sciatic nerve of the green frog compressed by a blast from an air pistol, we should have expected to have obtained better evidence of the immediate discharge which preceded partial or complete block in their preparation, and of the repetitive spikes initiated in the blocked fibers. If the *sine qua non* of concussion is a depolarization of nerve cell membranes with resulting massive discharge, as Walker, Kollros and Case have stated, we should have expected tetanus of hind limbs to have been a constant concomitant of concussion of the spinal cord in the region of the lumbar enlargement. Since tonic spasm, when it did occur, was not clearly associated with any magnitude of blow or severity of block it cannot reasonably be said to have indicated concussion.

All evidence indicates that the lysis of Nissl bodies in postconcussion is directly referable to physical injury of the cells sustained at the time of concussion. In both brain concussion and spinal cord concussion morphological evidence of this immediate physical injury may be seen as a subtle intraneuronal disorganization. The postconcussional chromatolysis is clearly different from that following axon section or asphyxia. Finally, there is usually no evidence of inflammation following concussion.

Spinal cord concussion at the level of the phrenic nucleus or higher would perhaps lead to fatal arrest of respiration. We have made no study of the effect of high blows because the topography of the cervical region practically precludes the possibility of uncomplicated spinal cord concussion.

There is reason to believe that spinal cord concussion as suffered by man is more severe in its physiological aspects than in the cat. In the cat a midthoracic blow does not alter the threshold for the femoral-sciatic reflex but in man it probably would, due to the much greater depth of spinal shock to which man is subject. Perhaps intervention of spinal shock can in some way lengthen considerably the period of functional recovery following a reversible spinal cord injury. In addition there is the possibility that spinal cord concussion can be more severe in man than in laboratory animals because of the greater strength of the vertebral column and consequently the greater force that can be applied to the nervous tissue without producing complication.

A major aim of the present study is clarification of the term, concussion. Persistent use of it to cover traumatic injuries of the brain and spinal cord displaying the most diverse clinical and pathological findings has greatly muddled thinking and writing on this important subject. This state of affairs is mildly indicated in so recent and excellent a book as *Injuries of the Skull, Brain and Spinal Cord*, edited by Brock, where different

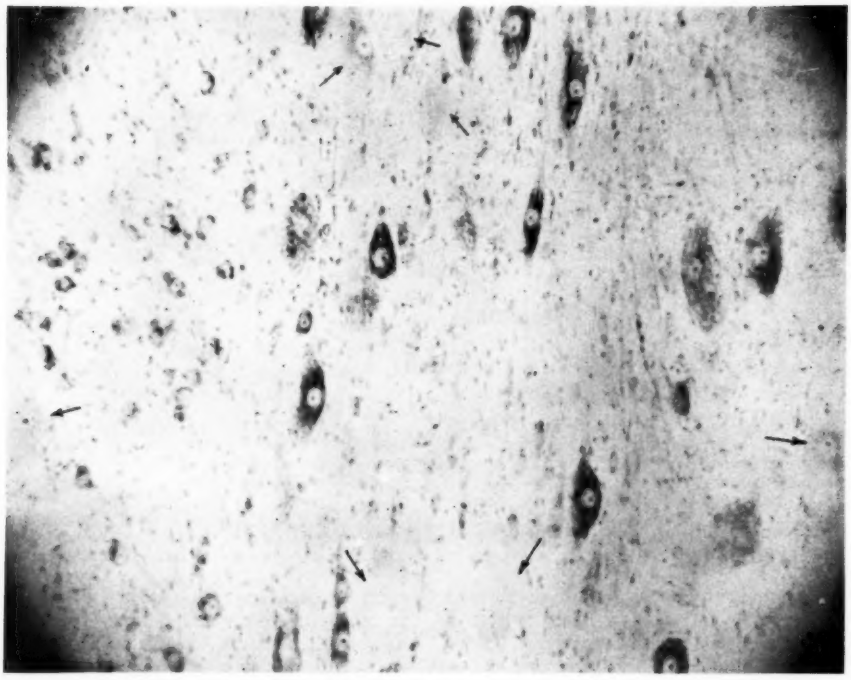


Fig. 9. Area of dorsal gray column including Clarke's column of cells. The chromatolyzed interneuron at the extreme left is not in Clarke's column. Arrows indicate chromatolyzed cells. × 145.

writers used concussion in different senses and the editor found it necessary to add explanatory remarks and guiding notes at several places. This should be corrected, not arbitrarily but on a practical and a sound basis.

If the term, concussion, is to be applied to both brain and spinal cord injuries, let the functional and pathological basis for application in the two instances be as similar as possible. Concussion of the brain has been shown to be a state immediately following application of an adequate force to the brain, a state in which chiefly the interneurons are incapacitated, resulting in a transient paralysis even though cranial motor nuclei are usually not significantly affected. Structural alterations in interneurons have been demonstrated in concussion and chromatolysis has been shown to occur in the early postconcussion period. Except for fiber damage sometimes perceptible in early postconcussion, this is the extent of the pathology in and after simple concussion of the brain (42, 14).

Earlier, both clinical and experimental reports appeared in which traumatic hemorrhages, contusions, and lacerations were confused with concussion and more or less severe degenerative processes following injury were described under the heading, concussion of the brain. On the other hand, there were those writers who believed that concussion of the human brain was marked by brief unconsciousness and chiefly paralytic effects unaccompanied by any anatomical changes. This latter view was a step toward order in classification of head injuries.

Many previous investigators have reported experiments and patients in which spinal cord concussion was distinguished not at all or only figuratively from traumatic hemorrhages, contusions, lacerations, and severe degenerative processes. But there is little in the literature to indicate that anyone ever thought definitely of spinal cord concussion as a reversible injury with no anatomical basis. This is no reason to fail to recognize now the true nature of spinal cord concussion as a brief spinal cord block with fiber and interneuron involvement. Knight approached this understanding when he wrote that uncomplicated concussion of the spinal cord will resolve completely with time, but if the concussion masks an underlying

contusion the signs of the latter injury will become manifest as concussion passes off. Recovery from the symptoms of spinal cord concussion in humans, according to Knight, may occur within 24 hours or be delayed for a week or more.

The indiscriminate use of the terms, spinal cord concussion or spinal concussion arose in, and has been perpetuated by uncritical clinical, pathological, and experimental observations. Pathological studies in man were all on severely injured patients or else were not judiciously appraised from the etiological standpoint. All or part of the lesions found were assigned to concussion. In the laboratory, very severe injuries were inflicted on animals and were called concussion. No adequately correlated functional and histological experimental studies were produced. Consequently no one knew what sort of pathological picture a recovered case might have displayed. In addition, the attempt was never made to dissociate early functional disturbances from excess pathological changes, i.e., to discover the maximum functional aberrations which could occur with the minimum anatomical alterations. Hence, in the clinic and in the laboratory, trauma which affected the spinal cord without grossly contusing or lacerating it was said to result in concussion regardless of the real nature of the lesions. If the spinal cord was directly contused or lacerated by a missile or bone fragment, it was still said to have suffered concussion adjacent to, or even remote from the directly contused or lacerated area if those other parts showed any pathological changes. In this way concussion came to be used as a very nonspecific term and, what was most unfortunate, the use of other more specific terms was passively discouraged.

Erichsen wrote in 1886 (1st ed., 1875) that there are four forms of lesions leading to fatal results in cases of spinal concussion: (1) hemorrhage within the spinal canal; (2) laceration of the membranes of the spinal cord and extrusion of the medullary substance into the spinal canal; (3) extravasation into the substance of the spinal cord; and (4) disintegration and perhaps inflammatory softening of the spinal cord. Erichsen also mentioned molecular disturbance and anemia as causes of concussion. Further, he included as spinal cord concussion, cases in which injury was remote, perhaps not even affecting the vertebral region, followed by general nervous disease, and injuries in which symptoms were delayed and ran a slow course.

Obersteiner described as concussion a case of gunshot injury of the spinal cord. The survival time was 5 weeks. There was an extensive area of softening and widespread degeneration in the spinal cord.

Page in 1885 (1st ed., 1882) severely criticized the writings of Erichsen and others. He was of the opinion that their reports were based upon faulty interpretations and that there was no evidence for their conclusions. However, he contributed nothing constructive to the knowledge of spinal cord injuries.

Spiller reported fatal injuries in a kitten (39) and in a human being (40) which he called concussion of the spinal cord. Pathological alterations were minute hemorrhages and Marchi degeneration. In the kitten there were alterations of the anterior horn cells.

In 1900 Hartmann published a paper on uncomplicated traumatic spinal cord diseases. The title is somewhat misleading because by "uncomplicated" the author meant all the cases in which there was no persistent injury to the vertebral column such as fracture or unreduced dislocation. Symptoms set in at once or were delayed. The pathology included primary and secondary fiber degeneration, hemorrhages, foci of necrosis, degeneration of anterior horn cells, root degeneration, glia proliferation, blood vessel changes, and meningeal involvement. The blood vessel changes were considered to be very significant and to lie at the root of much of the other damage.

Holmes, Claude and Lhermitte (5, 6), Lhermitte (26), and Ferraro (11) reported on spinal cord pathology in soldiers in whom the vertebral column was injured by a projectile without the spinal cord receiving a direct wound. The cases were spoken of as concussion. Clinical symptoms were those of total or subtotal transverse cord lesions. All found foci of necrosis, cavitation, acute primary degeneration of nerve fibers and glia proliferation within several segments of the level of injury. Besides, Claude and Lhermitte (5) and Lhermitte (26) found spinal nerve root degeneration and alterations of the central canal. They declared that the bodies of nerve cells of the gray substance were remarkable in their resistance to concussion. In addition, Ferraro (11) found focal hemorrhages and changes in the walls of blood vessels. Holmes also found hemorrhages.

Marburg (30) and Marburg and Ranzi (31) described the pathology of the same type of war injury cases but refrained from applying the name concussion to any of them. The most important change, Marburg believed, was an alteration in the walls of blood vessels leading sometimes to occlusion. He felt that most of the other pathology was the result of vascular alterations.

Mott referred to a case as spinal concussion in which there was a paralysis of arms, legs, and intercostal muscles together with anesthesia below

the second cervical level; death followed in 2 days. Extensive meningeal and intramedullary hemorrhages were found. The cells in the phrenic nucleus at the fourth and fifth cervical segments were entirely destroyed. There was vacuolation of myelin and swelling of axis cylinders at the seat of the injury.

Hassin (16) reported as concussion of the spinal cord a case in which the patient tripped over a wire and fell, striking his right shoulder. He arose and resumed work. Weakness of the right hand was present 4 weeks later and by 11 months both arms and legs were weak and showed wasting. The patient died of pneumonia 18 months after the fall and shortly after a laminectomy which had revealed no evidence of fracture dislocation or dural lesion. There were widespread degenerative changes of the anterior horn cells associated with proliferative neuroglial alterations. There were microscopic foci of degeneration or softening in the anterior horns in the lower cervical region. The posterior horns and Clarke's column showed practically normal cells. Fiber degeneration was found in the lateral columns, involving the lateral corticospinal tracts, the lateral limiting zones and Gower's tracts. The fiber lesions were said to be secondary to the cell lesions, the delicate cells suffering most from the jar. Hassin attributed the slow onset and progressive course of the clinical symptoms to the time necessary for nerve fiber degeneration to become manifest. In this (16) and a later paper (17) Hassin stressed the incidence of concussion of the spinal cord even far away from the region directly affected.

Davison and Keschner attributed to concussion the foci of necrosis which they found at varying distances below the primary lesions in cases of compression fractures.

Two cases, in one the patient dying of sepsis in 28 days, in the other of uremia in 14 days, formed the basis for the statement of Baldwin that primary and secondary degeneration of nerve fibers, foci of softening and destruction of ventral horn cells are manifestations of concussion of the spinal cord.

Scheinker identified as concussion a case in which the motor symptoms of limb weakness and atrophy were of gradual onset and progressive course. The patient succumbed to respiratory paralysis in 6 months. Fiber degeneration appeared in peripheral nerves. In dorsal root ganglia, the nerve cells were practically normal and the posterior roots were only slightly affected. But in the anterior roots severe fiber degeneration occurred. Widespread severe fiber degeneration and chromatolysis of anterior horn cells were found in the spinal cord. Many of the vessels throughout the spinal cord were congested. Diapedesis of red blood corpuscles was found associated with vessels showing degenerative changes in the endothelium.

Clutton, Clark, MacDougall, Hartmann, and Casamajor, all reported as concussion similar cases in which back trauma was followed by paraplegia, loss or impairment of sensation, and retention of urine. The symptoms began to regress in a few days and recovery was nearly complete in approximately 2 to 6 weeks. The delayed recovery times probably indicate that the injuries were concussion plus complications.

As has been implied, previous experimental work has not been of aid in classifying or clarifying traumatic injuries to the spinal cord. The work of Schmaus, in 1890, purporting to be on spinal cord concussion, considerably influenced thought in this field. He cited fatal cases of three human beings and a cat to show that the fiber degeneration which is found in the spinal cord at death some time after injury is primary and is not due to some gross lesion which interrupts the fibers. Besides this fiber degeneration there were other severe alterations in the spinal cord, including hemorrhage, infection, softening, and cavitation. He produced spinal cord injuries in rabbits by striking repeated blows on a board laid on the back. It should be mentioned that this method of producing injury by many repeated blows, first used by Koch and Filehne in 1874 in brain injury studies and subsequently employed by others in spinal cord investigations, has no practical basis. In Schmaus' work the traumatization was extreme, countless blows being delivered over a period of a few or many days. He made no further studies on a number of animals which seemed completely recovered after the traumatization was stopped. In most cases lasting paralysis of the hind limbs resulted and atrophy appeared after the second week. These animals were sacrified or died 2 to 44 days after the beginning of the experiment. The thoracic region of the cord was studied chiefly. In some there were no histopathological findings in nerve fibers and cells. In general the animals which gave these negative results were those which lived only a short time. In the rest all anterior horn cells of the spinal cord showed changes which the author hesitated to interpret. He thought they might be normal for young animals or might indicate a molecular concussional change in the cells. The greatest change was a primary degeneration of nerve fibers. Present also were subdural hemorrhage, scattered intramedullary hemorrhages, softening, areas of gliosis, and cavity formation. Several of the rabbits also had pneumonia.

Kirchgaesser (20, 21) laid a rubber mat on the back of rabbits and struck repeated blows with a hammer on one or several days. Five animals were killed and one died after 8 to 13 days. These were studied by the Marchi and the Weigert methods. Five had suffered complete paralysis with partial or complete recovery. These showed extensive primary degeneration of nerve fibers at the level of the blow and ascending and descending degeneration elsewhere. In a sixth animal which had exhibited brief tetanic spasm only, the changes were not as great. Two animals with different degrees of trauma and paralysis were killed 15 to 17 days after the start of the experiments, and the material was used for Nissl and for Marchi preparations. Fiber degeneration was severe but cell changes were considered by Kirchgaesser to be practically negative and capable of playing only an incidental, secondary rôle to the striking fiber changes. These injuries were all called concussion.

Jakob produced spinal cord trauma, and although he did not specifically designate it concussion, others have done so. The injuries were produced in rabbits by striking hammer blows against a board laid on the back. Two to 12 blows were delivered on 1 or 2 days. In 3 animals which died within half an hour there were no changes in the central nervous system except hemorrhages, but the liver was ruptured in 2 of them. In 3 animals killed 21 to 32 days after the first injury there were extensive primary and secondary fiber degeneration, variable degrees of softening and hemorrhages, a few scattered degenerating cells and heavier ganglion cell degeneration at the edges of the softenings and around the widened central canal. In an animal killed at 45 days there was secondary degeneration of fibers and in one killed at 4 months there were degenerating fibers and fresh hemorrhages. These last 5 rabbits were paralyzed in the hind quarters for periods ranging from more than 1 day to 21 days. Two animals were each dealt two light blows which produced short tetanus of the hind limbs without indications of paralysis; they were killed 2 days later. There was widespread diffuse fiber degeneration but no cell changes. In one of these animals there were a few small hemorrhages in the spinal cord.

Marinesco reported on experimental concussional lesions produced by exposing dogs to guncotton explosions. Lesions were most acute in those animals which lived 8½ hours after the injury. In the spinal cord punctate hemorrhages were especially numerous in the anterior and middle gray substance of the thoracic region. Nerve cells enclosed in these hemorrhagic foci were undergoing chromatolysis. The small periependymal vessels were congested and the central canal was irregular in contour. The cells of the spinal ganglia were normal despite hemorrhages about the ganglia and in the neighboring portion of the dorsal roots.

Mairet and Durante produced so called concussional lesions in rabbits by exposing them to the detonation of explosives. Early lesions in the spinal cord consisted of slight pial bleeding, perivascular ecchymoses more abundant in the white than in the gray matter and hemorrhages in the roots. Fiber changes were described but whether they were artifacts or true concussional alterations was left open. There were no changes in nerve cells of the spinal cord or dorsal root ganglia. Some animals were allowed to live for 5 to 9 months. They showed no abnormal behavior. No macroscopic lesions were found. In the spinal cord there appeared to be a size inequality of the anterior horns and a diminution in number of motor cells, many of which were small and without processes. In some cases fiber changes were seen near the periphery. There was no secondary degeneration in the white matter.

The work of Roussy, Lhermitte and Cornil is one of the most misleading publications on concussion of the spinal cord. These authors first reported on the results of direct trauma against the vertebral column in 6 guinea pigs and 1 rabbit. The animals were struck two to four times in the thoracic region. The injuries were severe, not only involving the vertebral column and spinal cord but also the viscera and ribs. The authors had trouble obtaining material for histological sectioning because of the morbidity of their animals. The animals used were saved as long as possible but their poor general condition always necessitated their sacrifice. The thoracic region of the spinal cord was studied microscopically. In 2 guinea pigs killed 15 to 20 minutes after the blows there was said to be acute primary degeneration of nerve fibers in the peripheral region—axis cylinders were hypertrophied, varicose, irregular and very fragmented and myelin sheaths were distended—and the neuroglial meshes were dilated. Two animals which had brief paraplegia and abnormal reflexes and were killed 7 and 8 days after the first blow, showed acute primary degeneration of nerve fibers in the marginal zone, dilated neuroglial meshes, but no changes in the gray matter. In 1 guinea pig and 1 rabbit killed 13 and 23 days after trauma, there were macroscopic regions of softening which microscopically proved to be areas of severe degeneration and necrotic foci affecting practically the whole cross section. Findings were negative in a guinea pig killed 5 months after injury. The

authors stated that findings in human pathology are the same—foci of insular necrosis and acute primary degeneration of myelinated fibers, the latter mainly in the peripheral region. These lesions, they stated, affect one or several segments of the cord at the level of the blow: this quite obviously seems to be a guess. The authors also reported a dog which was subjected to indirect trauma of the vertebral column. It was fixed with its back tightly against a board, anesthetized, and twelve violent hammer blows were struck against the board. The animal showed no abnormal signs when it awakened and in the following days seemed completely well. Two months later it became generally emaciated despite normal food intake. The wasting was progressive and 6 months after the trauma the dog was described as "skin and bones." Still, there were no neurological signs. The animal succumbed to this cachexia. The spinal cord was absolutely normal upon gross inspection. It was stained by a method for Nissl bodies. The anterior horn cells were frankly atrophied. The authors stated that these findings supported the thesis of Kirchgaesser (21) that the intensity of the cellular alterations was inversely (*sic*) proportional to the violence of the trauma. Kirchgaesser propounded no such theory. They contended to have shown that trauma directly on the vertebral column attacks chiefly the myelinated fibers of the white substance while indirect trauma of the vertebral column injures the cord less intensely, provoking cellular lesions more readily.

Ferraro (12) conducted histological studies in what he called spinal cord concussion in 9 rabbits killed 1 hour to 6 days after being struck on the back with an iron rod. Sections were stained with aniline blue and orange G. In his one hour animal he reported loose appearance of tissue in places, slight enlargement of some neuroglia cells, sharply demarcated areas in the white matter of deeply stained, enlarged and deformed axis cylinders with swollen myelin sheaths, occasional very minute foci of necrosis in the gray matter, some extravasation, nerve cells deeply stained, chromatin bodies of nerve cells condensed either along the periphery of the cell body or surrounding the centrally located nucleus, nucleolus sometimes dislocated along the nuclear periphery, neurofibrils conglutinated, and endocellular reticulum condensed. His 4 hour animal showed in addition to the above somewhat greater changes in nerve fibers and cells, cytoplasmic enlargement of ependymal cells and a few small spots of osmic reduction. In the 12 hour animal the nerve fiber and cell changes were further advanced, the connective tissue of the meninges was relaxed and thickened, blood vessel walls were thickened due to relaxation, and there were degenerative changes in spinal roots, especially the posterior. There were no lesions in the spinal ganglia. In the radicular zone of entrance some of the axis cylinders ended in enlargements, so called Schmaus bodies. In an 18 hour animal the lesions were more severe. There were empty holes left by degenerated axis cylinders. The nucleolus was occasionally displaced into the cytoplasm in nerve cells. In 30, 45 and 70 hour animals degeneration in the white matter was progressively more advanced. At 90 hours degeneration was diffuse and intense. At 6 days there was a pronounced neuroglial reaction. Nerve fiber degeneration was more advanced, many axis cylinders were gone without trace and osmic reduction was pronounced. Nerve cells, especially the anterior horn cells, sometimes showed the axon reaction.

These have been the principal findings in experimental pathological studies purporting to be of concussion of the spinal cord. Little comment is necessary. One of the outstanding deficiencies of previous work on the subject is lack of histological controls. The need for clarification of the term, concussion, is evident. Aside from that fact is the inescapable conclusion that many of the recorded observations are of questionable value.

It is clear that the functional alterations with their attending histological changes which we have described in this and in other papers (13, 14, 42) merit a specific designation from both a clinical and a pathological standpoint. This is true because these striking functional alterations have been shown to occur with a minimum of pathological change. It is to these injuries of the brain and spinal cord that the term concussion should be applied, and to these only, regardless of clinical frequency. This procedure then purges the whole of the remainder of the field of traumatic central nervous system afflictions of confusing and nonspecific terminology and permits of the accurate naming of the different clinical and pathological conditions. It is to be understood that trauma often results in a composite injury which should be named accordingly. It is further to be noted that the term, concussion, applies to the *result* of an extrinsic dynamic process such as a blow, not to that process itself.

SUMMARY

Spinal cord concussion was studied in cats. A blow applied over approximately the sixth lumbar spinal cord segment produced concussion, the severity of which was measured by the magnitude of increase and the duration of recovery time of

the threshold for a femoral-sciatic reflex. The severity of the concussion and the longitudinal extent of spinal cord involved increased with the strength of the blow. A blow producing concussion at the seventh and eighth thoracic segments did not spread sufficiently to produce concussion of the region of the cord involved in the reflex. Blows spaced from the eleventh thoracic down to the third lumbar segments caused progressively greater increase in threshold for the femoral-sciatic reflex.

A blow producing concussion at the lumbar enlargement caused a rise in threshold of a femoral-facial reflex. A blow producing concussion at the seventh and eighth thoracic segments did the same.

Stimulation was applied in the pyramid to evoke hind limb movement and slight forelimb movement. A blow at the lumbar enlargement caused a rise of threshold for hind limb movement. A blow at the seventh thoracic segment likewise readily caused an increase although forelimb movement, motor nerves for which originate from cord segments closer to the site of the blow, was little affected.

Occasionally an animal exhibited considerable general muscular activity on saphenous stimulation. A blow at the lumbar enlargement completely abolished this response while one at the level of the seventh thoracic segment extinguished it only rostral to the level of the blow.

In one-fourth of the instances in which concussion was produced at the level of the lumbar enlargement, the hind limbs immediately extended in tonic spasm lasting 5 to 25 seconds. The occurrence of spasm was unrelated to severity of concussion.

Histological studies were rigorously controlled. Examination of the affected region of the spinal cord of animals perfused immediately after the blow revealed subtle changes among all nerve cells except the motoneurons. The chief histological alteration found in the spinal cord 6 days after concussion was chromatolysis of nerve cells at a level underlying the external site of the blow. The principal participants in this reaction were interneurons of both dorsal and ventral gray columns. A comparison of the concussion material with spinal cords from animals in which ventral roots had been sectioned intradurally revealed 2 pertinent points. First, only relatively few motoneurons (cells which underwent chromatolysis following severance of ventral roots) underwent chromatolysis after concussion, and those were located within a few millimeters of the center of the affected length of spinal cord. Second, most of those chromatolyzed motoneurons found 6 days after concussion were in a stage of degeneration far beyond that of motoneurons 6 days after ventral root section.

Uncomplicated concussion of the spinal cord in the cat, then, is a complete functional block of the spinal cord at the level of application of an adequate force to the nervous parenchyma. Nerve cells, principally interneurons, and long ascending and descending fiber tracts are involved. The period of concussion is brief, passing into the period of postconcussion when the paralysis ceases. The much greater depth of spinal shock to which man is subject perhaps adds to the profoundness of the functional alterations in man. Subtle but histologically demonstrable cell alterations occur in concussion, and frank chromatolysis is evident in postconcussion as a direct result of the physical injury of the cells sustained at the time of concussion.

A review of the literature on spinal cord concussion supports the statements that the term, concussion, must be clarified, and that many of the recorded observations on spinal cord concussion are of questionable value. The functional alterations with their attending histological changes which we have described in this and in other papers merit a specific designation. It is to these injuries of the brain and spinal cord that the term, concussion, should be applied, and to these alone.

REFERENCES

1. BALDWIN, ROBERT S. Arch. Neur. Psychiat., Chic. 1934, 32: 493–500.
2. BROCK, SAMUEL. Injuries of the Skull, Brain and Spinal Cord. 2d ed. Baltimore: The Williams & Wilkins Co., 1943.
3. CASAMAJOR, LOUIS. N. York State J. M., 1921, 21: 99–101.
4. CLARK, F. LEGROS. Lancet, 1892, 1: 1078.
5. CLAUDE, HENRI, and LHERMITTE, J. Ann. méd., Par., 1915, 2: 479–506.
6. Idem. Rev. méd., Par., 1916, 35: 535–554.
7. CLUTTON. Lancet, 1891, 2: 928–929.
8. DAVISON, CHARLES, and KESCHNER, MOSES. Arch. Neur. Psychiat., Chic., 1933, 30: 326–341.
9. DUSSER DE BARENNE, J. G., GAROL, H. W., and MCCULLOCH, W. S. J. Neurophysiol., 1941, 4: 287–303.
10. ERICHSEN, JOHN ERIC. Concussion of the Spine. 3d ed. New York: William Wood & Co., 1886.
11. FERRARO, ARMANDO. Cervello, 1922, 1: 361–445.
12. FERRARO, ARMANDO. Arch. Neur. Psychiat., Chic., 1927, 18: 357–373.
13. GROAT, R. A., MAGOUN, H. W., DEY, F. L., and WINDLE, W. F. Am. J. Physiol., 1944, 141: 117–127.
14. GROAT, R. A., WINDLE, W. F., and MAGOUN, H. W. J. Neurosurg., 1945, 2: 26–35.
15. HARTMANN, FRITZ. Jahrb. Psychiat. Neur., Wien., 1900, 19: 380–472.
16. HASSIN, G. B. Arch. Neur. Psychiat., Chic., 1923, 10: 194–211.
17. Ibid. Arch. Neur. Psychiat., Chic., 1925, 13: 369–377.

18. HOLMES, GORDON. Brit. M. J., 1915, 2: 769–774.
19. JAKOB, ALFONS. In Histologische und histopathologische Arbeiten ueber die Grosshirnrinde. Edited by Franz Nissl and Alois Alzheimer. Vol. 5, pp. 182–341. Jena: Fischer, 1913.
20. KIRCHGAESSER, GISBERT. Deut. Zschr. Nervenh., 1897, 11: 406–419.
21. Ibid. 1898, 13: 422–431.
22. KNIGHT, GEOFFREY. In War Wounds and Injuries. Edited by E. Fletcher and R. W. Raven. Pp. 174–187. Baltimore: The Williams & Wilkins Co., 1940.
23. KOCH, WILHELM, and FILEHNE, WILHELM. Arch. klin. Chir., 1874, 17: 190–231.
24. KOENIG, HAROLD, GROAT, RICHARD A., and WINDLE, W. F. Stain Technology, 1945, 20: 13–22.
25. KREMS, A. D., SCHOEPFLE, GORDON M., and ERLANGER, JOSEPH. Proc. Soc. Exp. Biol., N. Y., 1942, 49: 73–75.
26. LHERMITTE, M. JEAN. Ann. méd., Par., 1917, 4: 295–307.
27. LLOYD, DAVID P. C. J. Neurophysiol., 1941, 4: 525–546.
28. MACDOUGALL, J. A. Lancet, 1892, 1: 863–864.
29. MAIRET, A., and DURANTE, G. Rev. neur., Par., 1919, 35: 97–110.
30. MARBURG, OTTO. Arb. Neur. Inst. Obersteiner, 1919, 22: 498–556.
31. MARBURG, O., and RANZI, E. Arch. klin. Chir., 1918–1919, 111: 71–282.
32. MARINESCO, G. Rev. neur., Par., 1918, 34: 329–331.
33. MOTT, FRED W. Tr. M. Soc. London, 1916, 39: 157–226.
34. OBERSTEINER, HEINRICH. Med. Jahrb., 1879, nos. 3 and 4: 531–562.
35. PAGE, HERBERT W. Injuries of the Spine and Spinal Cord. 2d ed. London: J. & A. Churchill, 1885.
36. ROUSSY, G., LHERMITTE, J., and CORNIL, L. Ann. Méd., Par., 1920, 8: 335–353.
37. SCHEINKER, I. MARK. J. Neuropath. Exp. Neur., 1942, 1: 181–187.
38. SCHMAUS, HANS. Arch. path. Anat. Physiol., 1890, 122: 326–356, 470–495.
39. SPILLER, WILLIAM G. Am. J. M. Sc., 1899, 118: 190–198.
40. Idem. Univ. Pennsylvania M. Bull., 1903, 15: 483–488.
41. WALKER, A. EARL, KOLLROS, JERRY J., and CASE, THEODORE J. J. Neurosurg., 1944, 1: 103–116.
42. WINDLE, W. F., GROAT, R. A., and FOX, C. A. Surg. Gyn. Obst., 1944, 79: 561–572.

IMMEDIATE SKIN GRAFTING FOLLOWING INJURIES

M. K. KING, M.D., F.A.C.S., Norfolk, Virginia

WOUNDS which can be surgically cleansed, débrided, and closed within 6 hours after injury usually heal by primary union. This applies to compound fractures as well as injuries to soft tissues. The secret of such healing is surgical cleansing and is dependent on no antiseptic or bacteriostatic drugs. We have adequately demonstrated this principle in treating several thousand injuries over the past 10 years. Before the introduction of the sulfonamides, we routinely closed compound fractures and other injuries when they were seen early.

In war wounds such treatment is not recommended. There is neither the time nor facilities available for the meticulous cleansing and débridement necessary in those first few golden hours. On the home front most patients with injuries come to the hospital early and the conditions are such as to make closed methods of treatment safe and practical.

To be successful, cleansing must be thorough. Every particle of foreign material and devitalized tissue must be removed from the wound. This treatment requires time, patience, adequate anesthesia, and plenty of soap and water. A stiff brush may even be necessary to remove dirt ground into the end of a bone, or the bone may have to be cut back for a short distance. Unless one is certain that all dirt has been removed, it is safer not to do a primary closure.

We have some additional safeguards in the sulfonamides when they are used in addition to, and not as a substitute for, surgical cleansing. Sulfanilamide crystals is the usual drug of choice. It may be frosted into the wound just before closing. It undoubtedly has decreased the incidence of infections in wounds when properly used, but it should be stated most emphatically that sulfanilamide will not prevent infection in a dirty wound.

Primary healing frequently means a saving in time of weeks or even months. It means decreased hospitalization and expense. It means minimum pain and deformity with maximum functional result.

Unfortunately, many wounds cannot be closed primarily because of loss of soft parts or because of swelling. By means of skin grafting many such wounds can be closed and primary healing achieved. A few examples of such injuries will be discussed.

From the U. S. Marine Hospital, Norfolk, Virginia.

ABRASIVE WOUNDS

This type of injury is usually produced by contact with grinding tools, by being dragged over a roadway, or by contact with a moving cable or rope. The wound is painful and dirty, and the dirt is ground into the underlying tissues.

Treatment consists of thorough surgical cleansing under adequate anesthesia and covering the surface with a partial thickness graft (Fig. 1). Local anesthesia is inadequate. Pentothal is usually very satisfactory. The wound is covered with sterile gauze until the remainder of the limb is thoroughly scrubbed with soap and water and ether. The wound is then irrigated gently, and particles of dirt and devitalized tissue are removed with forceps. Sharp dissection should be used when necessary. A small continuous stream of sterile water or saline facilitates the cleansing. Cleansing and débridement should be continued

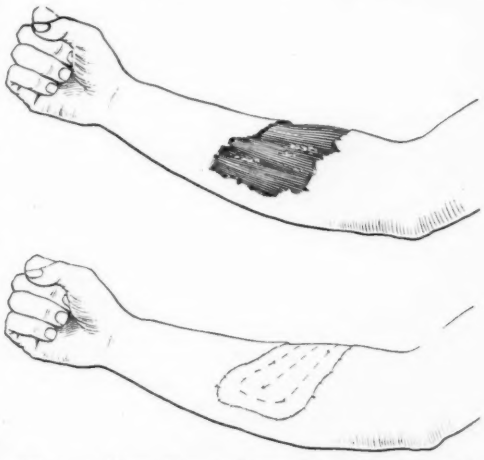


Fig. 1. a, above, Wound of forearm in which the superficial structures have been torn away down to the muscle. b, below, After thorough surgical cleansing and débridement wound has been converted into a "closed wound" by means of a partial thickness graft. The graft is 0.018 inch and was taken from the thigh with a Padgett dermatome. Note the basting type of suture which is used to hold the graft in firm apposition with underlying tissues and which also allows escape of serum. All sutures are fine black silk.

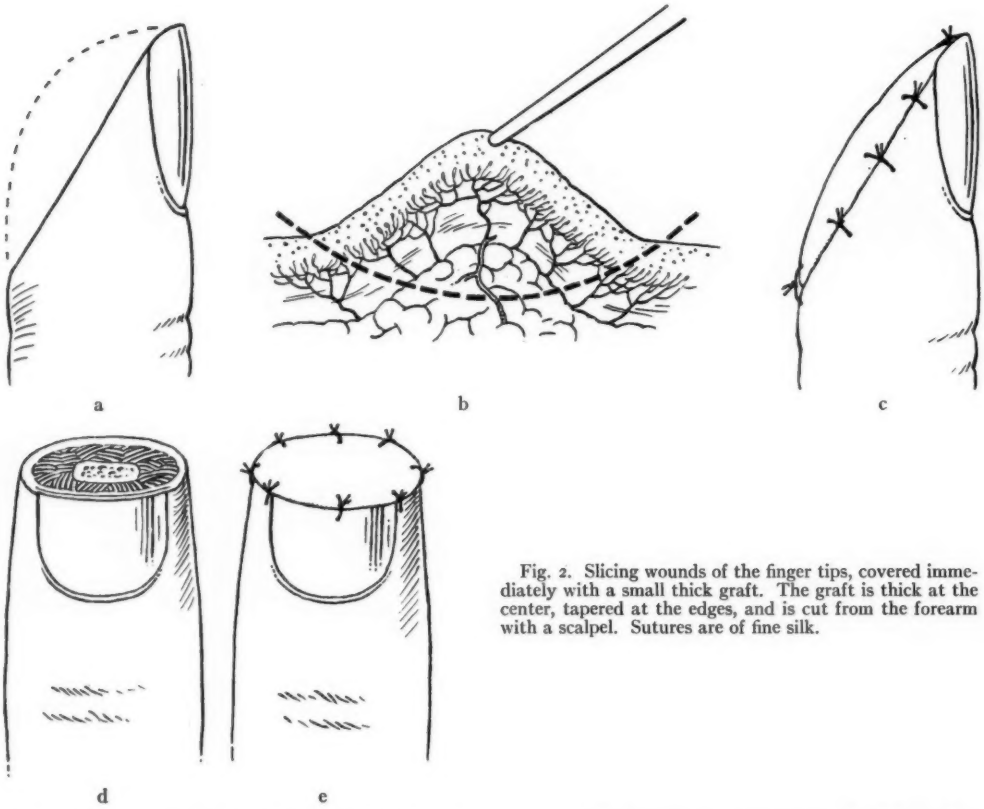


Fig. 2. Slicing wounds of the finger tips, covered immediately with a small thick graft. The graft is thick at the center, tapered at the edges, and is cut from the forearm with a scalpel. Sutures are of fine silk.

until one has a surgically clean wound with only healthy viable tissue remaining.

Finally the surrounding area is painted with merthiolate, and the wound is draped with sterile sheets. A partial thickness skin graft is taken from a convenient area sufficient to cover the wound. The cutting may be done with a knife or razor, but the Padgett dermatome is far superior for covering large areas. Furthermore, the grafts are more uniform in size and thickness, and there is less damage to the donor site. A graft of 0.014 to 0.018 inch is easy to handle, gives a good cosmetic result and leaves a donor site which heals rapidly without scarring.

Before the graft is applied, the wound is frosted lightly with crystalline sulfanilamide. The graft is sutured in position under slight tension, by means of fine silk on an atraumatic needle. A quilting pattern of sutures is used to bring the graft into firm apposition with the underlying bed, and these sutures decrease the need for accurately applied pressure postoperatively (Fig. 1, b). They also allow serum to escape and obviate the necessity for cutting holes in the graft. It does not matter if a few islands of the original skin are present beneath the graft. When suturing is completed, the whole area is again sprinkled lightly with sulfanilamide crystals, a gauze sponge saturated with sterile glycerine is pressed down firmly on the graft, and bulky gauze dressings are applied. Moderate pressure is maintained with adhesive strapping or elastic bandage. We have found special dressings unnecessary. Mechanics' waste is too lumpy and gives an uneven pressure. The outer dressings are removed in 5 days, and if the wound is clean and dry, it is redressed and after another 5 days the sutures are removed.

If the details outlined are followed, a 100 per cent "take" of the graft should be obtained. Healing time is greatly shortened, discomfort is minimized, and the cosmetic result is excellent in this method of treatment.

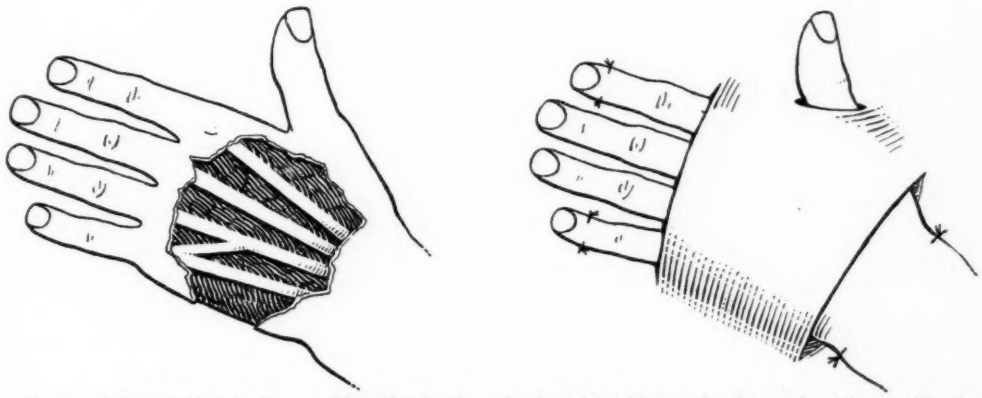


Fig. 3. a, left, Wound of the dorsum of hand leaving extensor tendons exposed. If the tendons are not covered, sloughing may be expected with crippling and deformity. A partial thickness graft will not give good function. b, right, After surgical cleansing and débridement, the hand has been placed in a pocket flap on the abdomen. The flap is thick and carries some fat. Note the anchor sutures to prevent movement of the hand. One end of the flap is divided in 7 to 10 days, the other in 12 to 17 days. The abdominal defect is covered with a partial thickness graft.

SLICING WOUNDS OF THE FINGERTIPS

Slicing injury of the fingertips is common in those working with knives, sharp-edged tools, or machinery. If the wound is allowed to heal spontaneously, it means healing by granulation and almost always results in a tender or painful scar. Many patients will return later requesting amputation for relief of these symptoms. If primary closure is attempted, it is necessary to shorten the bone in order to secure an adequate skin flap.

Immediate application of a thick skin graft to the wound will give rapid healing, good function, and will avoid further shortening of the finger (Fig. 2). The operation is a minor one and can be performed in the office or dressing room under procaine block anesthesia. The whole hand is thoroughly scrubbed. Usually very little cleansing of the wound is necessary since it is a smooth cut with free bleeding. Bleeding can be adequately controlled by pressure. The graft is cut from the flexor surface of the upper forearm in the same manner as a large pinch graft. A pattern is unnecessary for such a small graft. In females it may be desirable to use some portion of the anatomy other than the forearm. The graft should be full thickness at the center with a little of the subcutaneous tissue and tapered at the edges. It is sutured into position with fine interrupted silk. Sulfanilamide powder is sprinkled about the wound, a glycerine gauze dressing applied, and the finger bandaged under slight pressure.

Rapid, clean healing usually follows this procedure and a successful take may be expected in over 80 per cent of wounds so treated. Pain practically disappears after the graft is applied, and whether the graft survives or not, pain is greatly minimized in contrast to that seen when the wound is left open. Indeed, this is true of nearly all wounds treated by skin grafting. A very painful burn will become almost painless once it is covered with skin.

WOUNDS LEAVING EXPOSED TENDONS

Injuries in which the tendons are left exposed always lead to considerable disability unless

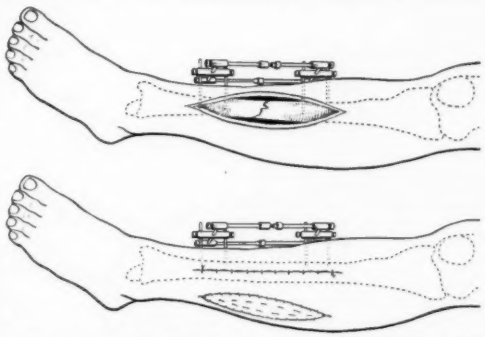


Fig. 4. a, above, Compound fracture of the tibia and fibula. The wound is meticulously cleansed and the fracture reduced under direct visualization. It is necessary to enlarge the wound to carry out this procedure. Most important single feature in treatment is thorough mechanical cleansing and débridement. b, below, Because of swelling, the operative wound could not be closed until a relaxing incision was made below. The open wound at the site of this secondary incision was then covered with a partial thickness skin graft from the thigh.

promptly treated. The exposed tendons either slough or become embedded in deep cicatrix. The hand is particularly vulnerable to such injuries, especially the dorsal surface where the coverings are thin.

Full thickness skin grafts are essential to good function in covering tendons. The grafts should carry a small amount of subcutaneous fat and areolar tissue. A free graft of this type does not take well when placed over exposed bone or tendons. A pocket flap should be used for the hand, and a pedicle flap for the ankle, foot, or knee.

For the sake of brevity, we shall discuss one injury of this type, a wound involving the dorsum of the hand (Fig. 3). Meticulous surgical cleansing and débridement are carried out and the injury is converted into a surgically clean wound free of devitalized tissue. The preparation is essentially similar to that described under deep scraping wounds. Exposed nerve filaments should be carefully preserved.

For the donor site, an area is selected in which the hand will fit comfortably without tension. The anterior abdominal wall or thigh is suitable. A flap is raised of sufficient size to fit over the hand and cover the wound. The hand is placed in this pocket and sufficient sutures used to anchor the flap firmly to the hand (Fig. 3, b). A few additional stout sutures are used to anchor the hand to the abdomen or thigh. Firm anchorage is most important. Movement of the hand under the flap is probably the greatest single factor in preventing a satisfactory result. Bulky dressings and adhesive strapping give additional immobilization when the operation is completed.

One end of the graft is cut free in 7 to 10 days. The free end is trimmed and fitted to the wound and sutured with fine silk or dermal. The other end is freed in 12 to 17 days and the final stages of fitting and suturing completed. The donor site can usually be closed but if necessary a split thickness graft may be used to cover the defect.

Approximately normal tendon function may be expected following this method of treatment. The procedure is equally applicable to secondary sloughs following injuries or burns, provided infection is cleared up before grafting is attempted.

MISCELLANEOUS

In compound fractures of the forearm or leg, it is sometimes impossible to close the wound following operation. Relaxing incisions must then be made lateral to the wound in order to bring full thickness skin and fascia together over the bone. The relaxing incisions instead of being left open to granulate in may be covered with a split thickness graft (Fig. 4). The technique of application is similar to that described under scraping wounds. A graft of 0.014 inch is satisfactory. In this manner rapid, clean healing is assured with minimum disfigurement.

In a dirty crushing or deep lacerated wound, it is sometimes advisable to excise the whole area, thus converting it into a clean surgical wound. Following excision, it may be difficult or impossible to bring the edges together. A partial thickness graft taken from an adjacent area may be used to convert this into a closed wound. The technique is similar to that described, except that in a deep wound greater care must be taken to bring the graft into contact with the underlying base. This contact is accomplished chiefly through suturing with fine silk and by the use of pressure dressings.

SUMMARY

Through the use of skin grafting, many open wounds can be converted into closed wounds, and thus primary healing obtained. Primary healing means a tremendous economic saving as well as decreased pain, improved function, and superior cosmetic results.

To be successful, all dirty wounds must be surgically clean before grafting is attempted. Grafts must be placed and held in firm apposition with the underlying tissues. The most common causes of failure in skin grafting are: (1) infection; (2) blood or serum pockets beneath the graft; (3) inadequate contact between the graft and its bed; (4) improper or inadequate anchorage of the graft, so as to allow movement during the healing period.

A variety of injuries are discussed in some detail, with methods of grafting best suited to each type.

DICUMAROL THERAPY IN POSTOPERATIVE THROMBOPHLEBITIS AND PHLEBOTHROMBOSIS

WILLARD H. PARSONS, M.D., F.A.C S., Vicksburg, Mississippi

THE outlook in postoperative pulmonary embolism, which was formerly regarded as an unpredictable, unpreventable, and highly fatal surgical complication, has been completely altered within the last few years for two important reasons. The first is a changed concept of its etiology. The second is the introduction of effective prophylactic and therapeutic measures, including ligation and division of the femoral vein and, more recently, the use of dicumarol.

It is still true that in all surgical experience there are few more ghastly accidents than the sudden death from massive pulmonary embolism of a patient who, until the fatal episode, has been progressing to an uneventful recovery. There is no longer any justification, however, for the former concept that the catastrophe is a literal bolt from the blue. It is not. It is now realized that in probably 95 per cent of all cases postoperative pulmonary emboli which terminate fatally have their origin in thrombosis, often without an associated inflammatory factor, of the superficial or deep veins of the lower extremities.

Both the incidence and the causation of postoperative thrombi are still matters of debate. On the surface, at least, geography seems to have something to do with the incidence. Thus Allen, Linton, and Donaldson report a very high frequency in Boston, while Ochsner and DeBakey report a considerably lower incidence in the South. What is important, however, is that wherever the condition has been properly studied, the incidence has always been found to be much higher than was once believed or than is believed and taught in many circles at the present time.

The incidence of postoperative thrombosis, regardless of the locality, is always directly related to the proportion of necropsies secured. Whenever the proportion is high, there is a correspondingly high incidence of thrombosis of veins of the lower extremities and of pulmonary infarction and fatal pulmonary emboli. When the percentage of necropsies is low, the incidence of venous thrombosis and pulmonary infarction and of fatal pulmonary emboli is correspondingly small. For the past 5 years I have been able to obtain necropsies in about 75 per cent of all fatal cases on my own surgical service, and I have observed—on more than one occasion to my amazement and chagrin—a relatively high incidence of pulmonary embolism and of antecedent venous thrombosis. My experience in this respect, I am sure, is not unique.

Although there is no general agreement as to all the causes of venous thrombosis, certain causes are established, including (1) improper handling at operation of the viscera and their venous supply; (2) confinement to bed, with consequent inactivity of the limbs, and, in turn, slowing of the circulation; (3) some alteration of the normal blood clotting time, the nature of which and the reasons for which remain to be elucidated. The complication is most often observed after surgery, particularly upon the pelvic organs, and pelvic infection, either antecedent to or subsequent to operation, unquestionably is an important cause. It should be emphasized, however, as the following cases illustrate, that a nonpelvic origin is not infrequent, and that surgery does not necessarily precede the development of pulmonary embolism.

CASE 1. M.J.H. (H-13-873), a negro woman 25 years of age, submitted to subtotal thyroidectomy for toxic nodular goiter November 2, 1943. She was discharged in good condition 7 days later, after an uneventful recovery. No abnormalities were observed at the first postoperative examination, November 15, but at the second examination, November 24, swelling of the left lower extremity was noted, and by December 11 a clearcut thrombophlebitis had developed. Routine measures were instituted and were followed by complete recovery except for residual edema, which also disappeared after paravertebral block of the first to fourth left lumbar ganglia, inclusive, March 3 and March 11, 1944.

CASE 2. D.W.S. (H-14-622), a negro man 22 years of age, was first seen April 8, 1944, on the medical service of Dr. W. K. Purks. For the past month he had had a "head and chest cold," with a cough, productive at night, and had lost 14 pounds. Roentgenologic examination of the chest showed bilateral far advanced pulmonary tuberculosis, and examination of the sputum revealed acid fast bacilli. April 19, while in the waiting room, the patient suddenly developed cyanosis and dyspnea, passed into a state of shock and died 12 hours later, having failed to respond to all therapeutic measures. Necropsy confirmed the diagnosis of extensive bilateral pulmonary tuberculosis and revealed the immediate cause of death to be pulmonary embolism; it also revealed thrombosis of the right femoral vein and multiple pulmonary infarcts from previous emboli.

From the Vicksburg Clinic, Vicksburg, Mississippi. Read by invitation before the Pike County Medical Society, August 3, 1944, at McComb, Mississippi.

Thrombosis (whether the bland thrombosis of Homans or the phlebothrombosis of Ochsner) should be borne in mind as a possibility following any operative procedure and should be immediately presumed to exist if several days following surgery there is unexpected or unexplained low-grade fever or if there is tenderness in the calf of the leg on dorsiflexion of the foot (Homans' sign). These two phenomena are sufficient for diagnosis. Phlebography is not essential; it is sometimes useful, but it may be very unwise.

When thrombosis or thrombophlebitis has been diagnosed or is seriously suspected, exploration of the femoral vein is a wise precaution. If pulmonary infarction has developed, it should be carried out without delay. Although a highly effective procedure, exposure and exploration of the femoral vein with removal of the clot by suction are minor in their scope, present no surgical hazards, give rise to no complications, and can be safely and quickly carried out, even on a very ill patient.

DICUMAROL THERAPY

With this plan of treatment, itself of fairly recent development, should be combined the administration of dicumarol controlled by daily determinations of the plasma prothrombin time. The effectiveness of these measures is illustrated in the following case report:

CASE 3. R. H., a white female 28 years of age, submitted to complete hysterectomy for uterine fibroleinomyomas and cervical erosion June 28, 1944. She was discharged in good condition July 10, after an uneventful recovery, but was rehospitalized July 13 because of pain in the upper third of the left thigh, just below Poupart's ligament, associated with slight swelling and slight reddening of the skin over the affected area. The left femoral vein was immediately exposed and opened, a clot 8 inches in length was removed, and the vein was then ligated and divided. Dicumaral therapy, under laboratory control, was administered until July 21 and the patient was discharged the following day, completely recovered.

Thrombosis of the veins of the lower extremities can be prevented in most cases by certain precautions at operation and following operation. At operation all manipulations should be nontraumatic and there should be special regard for the venous supply. After operation active circulation should be maintained in the lower extremities by keeping them warm, by the use of exercises, preferably with the bicycle apparatus, and, in older patients, by the application of snug fitting bandages. The prophylactic use of dicumarol is also of value, as the following case report indicates:

CASE 4. Mrs. R. H. (H-15-021), a white female 39 years of age, submitted to total hysterectomy for uterine fibroleinomyomas July 21, 1944; prophylactic appendectomy was also performed. Because she was frankly fearful of pulmonary embolism, from which two close relatives had died following operation, dicumarol was given for 6 days before operation, the day of operation, and for 3 days afterward. Recovery was completely uneventful.

The case is somewhat similar to a case in Zucker's series in which dicumarol was used prophylactically because the patient had a previous history of thrombophlebitis in pregnancy, one sister had died of postpartum thrombophlebitis, and a second sister required amputation of a lower extremity for the same reason.

The discovery by Schofield of the part played by spoiled sweet clover in the hemorrhagic diseases of cattle was followed by the isolation and synthesis of its active principle, dicoumarin, and by the prophylactic and therapeutic use of this principle under the commercial name dicumarol. Although reports in the literature are still few, there seems no doubt of the effectiveness of this anticoagulant. Barker and his associates from the Mayo Clinic, who tested it prophylactically over a 3 year period, in 1943 published their results in 497 cases. In 75 of these cases, on the basis of existing statistical data, thrombosis or embolism might have been expected to occur, and 24 fatalities from embolism might have been expected. These conditions, however, developed in only 4 instances, none of which terminated fatally. Zucker has recently reported 18 cases in which dicumarol was used therapeutically, including 9 instances of thrombophlebitis of the lower extremities and 2 instances of postoperative pulmonary infarction; all of the patients made uncomplicated recoveries.

The rationale of this form of therapy, reduced to somewhat oversimplified terms, may be stated as follows: Thrombosis and subsequent embolism, regardless of whatever other etiologic factors are involved, occur because the mechanism of blood clotting is too effective. The use of dicumarol is a deliberate attempt to reduce the efficiency of this mechanism to the lower limit of safety by the administration of an anticoagulant, under controlled conditions, over a certain period of time.

The plan of therapy is to administer an initial dose of 200 to 300 milligrams of dicumarol, followed by daily doses of 100 milligrams as long as is necessary to maintain the plasma prothrombin time within 30 to 60 per cent of normal. Observations at the Mayo Clinic by Hurn and her associates indicate that thrombosis will almost certainly not occur if the prothrombin time is longer than 27 seconds and that bleeding is very unlikely to occur after the administration of dicumarol if the prothrombin time is less than 60 seconds.

Their policy is to use 35 seconds as an arbitrary standard; when the prothrombin time is longer than 35 seconds, dicumarol is administered, and when it is less, the drug is omitted

Zucker calls attention to the importance of the tendency (slope of the plotted curve) of the plasma prothrombin time, which is equal to the importance of the absolute level. The time may be excessively and dangerously lengthened if an additional dose is given while the percentage of normal is decreasing, but there may be escape from the desired range if a dose is not given while it is increasing.

Dicumarol for either prophylactic or therapeutic purposes is absolutely contraindicated in purpuric disease of any type, in blood dyscrasias with a bleeding tendency, in renal insufficiency, and in hepatic disease, with which a prothrombin time deficiency is frequently associated. Even when these contraindications are observed, however, bleeding is always a possibility. It occurred in 47 of the 497 cases reported by Barker and his associates, though in only 18 of these, in all of which it was readily controlled by transfusion, was it apparently related to the anticoagulant therapy. In Zucker's series of 18 cases, 5 patients presented microscopic hematuria, in 1 instance associated with a petechial rash. In the latter case the rash developed while the prothrombin time was 18 per cent of normal, and in 3 of the other cases hematuria developed while the prothrombin time was less than 30 per cent of normal.

The speed with which the prothrombin time may be extended to dangerous levels is well illustrated in a personal case:

CASE 5. C. O. S. (H-14-887), a white man 45 years of age, submitted to Bassini hernioplasty June 7, 1944, for repair of a large left indirect inguinal hernia. Recovery was smooth until June 25, when sudden collapse occurred, associated with severe precordial pain and profuse sweating. Although coronary occlusion was first considered as a possibility, the presence of a pleural friction rub, the electrocardiographic data, and certain other evidence made a diagnosis of pulmonary infarction more reasonable, and dicumarol therapy was therefore begun with an initial dosage of 300 milligrams. On the following day 200 milligrams was given, and 100 milligrams was given June 27. The patient's plasma prothrombin time was 25 seconds (normal 15 seconds) June 26 and was 36 seconds (normal 15 seconds) June 27. Although no further medication was administered, the plasma prothrombin time rose to 46 seconds (normal 17 seconds) June 28, to 57 seconds (normal 15 seconds) June 29, and to 100 seconds (normal 15 seconds) June 30, at 10 A. M. At 11:45 A. M. on this date 20 cubic centimeters (64 mgm.) of hykenone (synthetic vitamin K, Abbott) was given. By 2:00 P. M. the plasma prothrombin time had fallen to 45 seconds (normal 17 seconds) and 3 hours later it had fallen to 30 seconds (normal 15 seconds).

The day after the patient's collapse indefinite edema of the left leg was demonstrated. On the following day edema was definite and was associated with tenderness over the course of the left femoral vein. The vein was exposed and incised June 28, a clot 4 inches in length was removed, and the vein was then ligated and divided. Recovery, after the correction of the dangerously prolonged prothrombin time, was uneventful, and the patient was discharged in good condition July 14, 1944.

The speed with which the prothrombin time in this case rose to dangerous levels and the rate at which it continued to increase for 72 hours after the drug was discontinued suggest that the patient was particularly susceptible to dicumarol. The even greater speed with which it returned to a safe level after a single administration of synthetic vitamin K suggests that this method is probably even more effective than transfusion, which is usually advised.

It should be noted that in this case the thrombophlebitis followed rather than preceded the development of pulmonary infarction, or, more correctly, became evident after the development of pulmonary infarction. It should also be noted that it became manifest while the patient was under treatment with dicumarol. Zucker, who recorded a somewhat similar instance, regards the development of the venous thrombosis under such circumstances as evidence of the safety of dicumarol therapy, though it also, he believes, raises the question as to whether hypoprothrombinemia achieved by dicumarol is sufficient to inhibit intravascular clotting.

Dicumarol therapy is potentially dangerous and the necessity of laboratory control by daily plasma prothrombin determinations cannot be overemphasized. The possible risks are illustrated in the personal case just described (Case 5) and are more tragically illustrated in the fatal case reported by Shlevin and Lederer. Their patient, a white woman 79 years of age, was first seen 4 weeks after she had been admitted to another institution for "thrombosis of the right retinal vein," for which she was treated for 21 days with daily doses of 100 milligrams of dicumarol. During this time no plasma prothrombin determinations were made, although the coagulation time was reported as 20 minutes. Dicumarol was discontinued 4 days before the patient was first seen by Shlevin and Lederer, when bleeding from the gums had occurred. It had persisted, and had been associated for 3 days with hematuria.

The patient was given 7 transfusions, after the first 3 of which oozing was temporarily controlled. The plasma prothrombin time, which was 60.6 seconds (control 12.1 seconds) when the patient was first seen, rose to 360 seconds plus (control 13 seconds) on the 8th day of hospitalization after the 4th transfusion, and was 84.4 seconds (control

12.8 seconds) when it was last determined. Acute left heart failure developed after the 2nd transfusion, and anuria on the 7th day was succeeded by incontinence, lethargy, and coma. Death occurred on the 14th day. At this time there were ecchymotic areas on shoulders, hips, legs and about the anus. The outstanding feature of the necropsy findings was marked engorgement of all blood vessels except the larger trunks; it was most pronounced in capillaries, arterioles, and venules.

This case, apparently the first of the kind to be reported, carries its own lessons and makes clear that too many precautions cannot be taken while dicumarol therapy is being administered. For this reason it seems well to mention the recent warning by Hurn and her associates that thromboplastin is distinctly variable under certain conditions, and that each new batch, regardless of the similarity of preparation, should be checked since the results of the prothrombin time test depend to a great extent on the activity of this agent. As these workers point out, when the Quick test was first introduced, all information desired was whether or not the prothrombin time was prolonged. With dicumarol therapy, however, the patient's safety depends upon knowledge of the exact amount of deficiency, hence the necessity of checking the activity of thromboplastin used in the test.

On the whole, dicumarol is a more practical drug for general use than heparin, which was formerly the only effective anticoagulant available. It can be given by mouth, whereas heparin must be given intravenously, which is always a disadvantage for the patient and which is often inconvenient in these days of shortages of hospital personnel. It is much cheaper than heparin which is almost prohibitively expensive for the majority of patients. It is also safer than heparin, in the opinion of some observers, because of its apparently low toxicity. On the other hand, dicumarol requires from 24 to 36 hours to take effect, whereas heparin acts almost at once, which means that in a certain small proportion of cases heparin rather than dicumarol is the preferred drug.

SUMMARY

Pulmonary embolism is preceded in the great majority of cases by thrombosis of the veins of the lower extremities, which can usually be prevented by the proper precautions at operation and afterward and which can be treated by removal of the clot from the femoral vein with subsequent ligation and division, supplemented by the administration of dicumarol. Dicumarol is also a valuable prophylactic measure.

In spite of its effectiveness, dicumarol, the essential effect of which is to lengthen the clotting time, is a very dangerous agent which should never be employed without adequate control in the form of daily estimations of the plasma prothrombin time.

If the plasma prothrombin time becomes dangerously lengthened, as may happen, even in properly controlled cases, in a subject especially susceptible to the drug, the administration of a vitamin K preparation or transfusion is indicated and seems promptly effective.

REFERENCES

1. Allen, A. W., Linton, Robert R., and Donaldson G. A. Ann. Surg., 1943, 118: 728–740.
2. Barker, N. W., Allen, E. V., and Waugh, J. M. Proc. Mayo Clin., 1943, 18: 102–107.
3. Campbell, H. A., Roberts, W. L., Smith, W. K., and Link, K. B. J. Biol. Chem., 1940, 136: 47–55.
4. Homans, John. Cited by Allen et al. (1).
5. Idem. N. England J. M., 1934, 211: 993–997.
6. Hurn, Margaret, Barker, N. W., and Magath, T. B. Proc. Mayo Clin., 1944, 19: 507–512.
7. Ochsner, Alton. Surgery, 1939, 6: 129–131.
8. Ochsner, Alton, and DeBakey, Michael. J. Am. M. Ass., 1940, 114: 117–124.
9. Schofield, F. W. J. Am. Vet. M. Ass., 1924, 64: 553–575.
10. Shlevin, E. L., and Lederer, Max. Ann. Int. M., 1944, 21: 332–342.
11. Zucker, H. D. J. Am. M. Ass., 1944, 124: 217–220.

THE EFFECT OF DIHYDROTACHYSTEROL ON CERTAIN TOXEMIAS OF LATE PREGNANCY

WALLACE SHUTE, Captain, R.C A.M.C., and EVAN SHUTE, B.A., M.B , F.R.C.S.C ,
London, Canada

PROPHYLACTIC control of pregnancy toxemias in the last, dangerous trimester has proved a very complex problem. No treatment can be adequate, however ingenious, if it fails to eradicate their cause. Etiological exploration to date seems to have progressed along four main approaches: (1) endocrines, (2) placental toxins, (3) kidney factors, (4) chemical or organic poisons from other sources. Prophylaxis has not waited, however, for a completed knowledge of etiology, and many workers have stressed the value of vitamins and better food in preventing toxemias or alleviating their symptoms.

In 1910, Mitchell made the observation, on empirical grounds, that an inadequate complement of calcium was a predisposing cause to the toxemias of pregnancy. Morel and Rathery found that a lowered detoxifying function of the liver followed parathyroidectomy and the resultant derangement of calcium metabolism. The liver, of course, is one of the principal sites of attack in eclampsia and other late toxemias of pregnancy.

Lopez found in his toxemia series that prompt improvement followed injections of Collip's parathyroid extract, with diuresis and a decrease in blood pressure, edema and subjective symptoms ensuing. In none of these was there any significant coincident increase in the blood calcium level.

Richardson reported complete symptomatic recovery of two pre-eclamptics who were given parathormone intramuscularly and calcium and viosterol by mouth. Blood pressures of 150 and 160, respectively, dropped to normal level, and even a two plus albuminuria disappeared rapidly.

Daly claimed similar dramatic results with the oral use of tablets containing a calcium salt, combined with the intravenous administration of a corresponding preparation. He made the interesting additional observation that only 11 per cent of his treated series were delivered prematurely as against 63 per cent of the controls.

J. C. Brougher reported a series of 88 toxemic patients occurring in a total of 1000 pregnancies. Of these, 34 had blood pressures of 150/100 and up, with varying degrees of ankle edema, albuminuria, and definite toxemic symptoms. The remaining 54 had pressures from 140 to 150, only slight ankle edema, and traces of albumin—no other toxic symptoms. Parathormone in 1 cubic centimeter doses was used to elevate the serum calcium. In each case diuresis occurred with prompt loss of edema, general weight loss, lowering of blood pressure, and a recession of toxic symptoms.

Theobald treated 50 healthy women, less than 6 months pregnant, with daily doses of 20 grains of calcium lactate as well as 11,000 international units of vitamin D. Only 7 of these developed hypertension, as against 17 in a group of 50 controls.

Similarly Mendenhall and Drake found in a group of 188 women given calcium orally that toxemia developed only twice (1 per cent). In a group of 230 controls fully 30 became toxic (13 per cent).

It has been shown (Albright and associates) that though parathormone increases phosphate excretion and mobilizes calcium, it does not aid in calcium absorption. Conversely, dihydrotachysterol (A.T. 10) plays an active rôle in increasing calcium absorption from the gastrointestinal tract, although it is less effective than parathormone in promoting phosphate excretion.

By means of blood estrogen estimations, we have found (12) that toxemic women fall into two main groups, namely: (1) those exhibiting a high blood estrogen level, characterized by either a tendency to abortion or miscarriage or abruptio placentae or premature labor; (2) a much smaller group with normal or low blood estrogen values, who, being true pre-eclamptics, may run almost the whole gauntlet of pregnancy very well, to all outward appearances, only at the end to fall over the precipice of convulsions. In the experience of the authors, women belonging to the first group very rarely convulse; the latter are always potentially capable of doing so.

The great majority of the first or high estrogen group of toxemic women respond to vitamin E prophylaxis satisfactorily throughout pregnancy (11). A certain small percentage of them, however, either do not respond perfectly at any time to such treatment or seem to escape from such

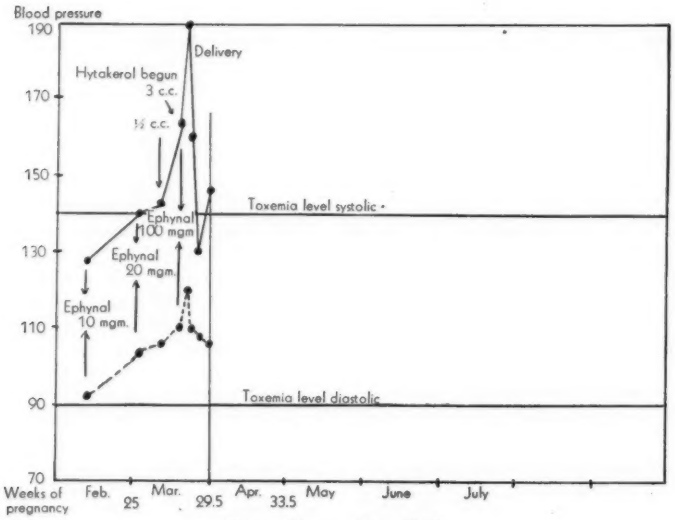


Fig. 1. Case 1. Mrs. R. B.

control at the end. It was for the management of this refractory and difficult group that the treatment outlined in this paper, the use of calcium and dihydrotachysterol, was thought of by one of us (W.B.S.).

DATA

There were 42 patients in the group studied, of whom 38 were of the high estrogen type and 4 of the low estrogen or true pre-eclamptic group. Each of these patients was given orally a daily dose of 20 to 30 grains of calcium gluconate or calcium diphosphate when the toxemia began to escape from vitamin E control. To promote maximum absorption of this calcium, dihydrotachysterol was given by mouth at the same time in the form of hytakerol (Winthrop). In the early cases blood calcium studies were performed repeatedly both before and during administration. However, it was soon discovered that with the doses given a qualitative urinary calcium estimation, using the Sulkowitch reagent (1), was quite adequate, and therefore the blood tests were demanded less frequently.

The Sulkowitch reagent is made as follows: oxalic acid, 2.5 grams; ammonium oxalate, 2.5 grams; glacial acetic acid, 5 cubic centimeters; distilled water, to 150 cubic centimeters.

To test for urine calcium equal parts of the reagent and urine are mixed. If a milky reaction promptly follows, calcium is being excreted in excess. The mixture should be allowed to stand in order to recognize any sediment of calcium oxalate. In the doses we have used there has often been a cloudy mixture and some sediment, but never a really milky reaction indicating hypercalcemia.

CASE HISTORIES

The details of a few illustrative cases are given here:

SUMMARY OF RESULTS

Classification	Number of cases	Results		
		Much improved	Slightly	Failed
High estrogen	38	16	6	16
Low estrogen (true pre-eclampsia)	4	0	0	4
Totals	42	16	6	20

Case 1. Mrs. R. B. This woman, aged 23 years, had her last menstruation on September 15, 1943. She gave a history of convulsive eclampsia with her other pregnancy which had ended, at 7 months, in a coma lasting 5 days. On February 10, 1944, when first seen, she had a blood pressure of 128/92, no edema nor albuminuria. Because her blood estrogen level was up she was at once given 10 milligrams of ephynal per day. On March 2 her pressure had jumped to 140/104 and she was given 20 milligrams of ephynal and 15 grains of dicalcium phosphate henceforth. In a week's time no improvement had ensued and therefore she was given ½ cubic centimeter of hytakerol per day as well. She now had a 2 plus albuminuria. By the 17th her pressure had jumped to 164/110, her albuminuria was 3 plus, and she was admitted to hospital for observation. On

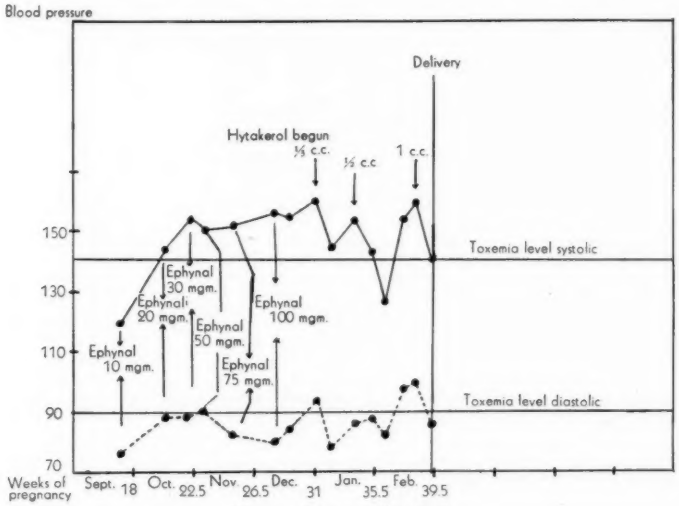


Fig. 2. Case 2. Mrs. J. F.

the 18th she was given 100 milligrams of ephynal per day, her pressure was 190/120, and her albuminuria was 1.0 milligram per cent. On March 21, on 3 cubic centimeters of hytakerol and 50 milligrams of ephynal per day her blood pressure was 140/110 and her albuminuria had decreased to 0.5 milligram per cent, where it remained. The Sulkowitch test was always negative. On the 23d her pressure was 128/98 and her albuminuria only a trace. She went home on the 27th. On March 31, her albuminuria was up again to 2 plus and her pressure to 146/106. On that same day she spontaneously ruptured the membranes and began labor. In an hour she delivered a boy weighing 5 pounds 2 ounces. The placenta followed soon, showing rather complete red infarction, leaving only a 3 inch square area resembling normal placenta. On April 1 her pressure was 152/112. On April 2 it was 122/90. On April 3 it was 112/82. She ran a fever for 2 days but sulfathiazole quickly controlled it. She has been well since.

Case 2. Mrs. J. F., a primigravida, aged 34 years. She was first seen September 22, 1942. Her last menstrual date had been May 26. Her urine was clear, her pressure 120/76, her weight 118 pounds. As she had a positive blood estrogen she was at once given 10 milligrams of ephynal per day. Her blood pressure began to climb steadily despite increasing doses of ephynal. She developed very marked uterine tenderness, too, and was almost unable to walk by January 2, 1943, when her pressure was 160/94, and her weight was 138. She still had no edema nor albuminuria. Her blood calcium was 9.7 millimeters per cent. She was then given 15 milligrams of calcium gluconate and 2 cubic centimeters of hytakerol per day. She had had 100 milligrams of ephynal per day for 3 weeks prior to this, and this dose was maintained. By the 9th her pressure had dropped to 144/78, her weight had gone down half a pound and the hytakerol was cut to ½ cubic centimeter per day. On February 6 her pressure was only 126/82. On February 20 her pressure had risen again to 160/100, and she was given 1 cubic centimeter of hytakerol per day. Labor began spontaneously on February 27 with a pressure of 140/85 and a trace of albuminuria. After an 8 hour labor a girl weighing 7 pounds 7 ounces was delivered by outlet forceps. The placenta showed two white marginal infarcts about 1½ and 3 centimeters in diameter, respectively. She made an uneventful recovery. On May 6 a catheter urine showed a trace of albumin. On May 29 her pressure was 140/106 when seen for an acute mastitis. She has remained well since.

Case 3. Mrs. D. K. First pregnancy in a woman of 27 years. Her last menses had begun on June 20, 1944. When first seen on September 10 her blood pressure was 140/90, and there was no albuminuria. As the blood estrogen was positive she was at once given ephynal. Despite 75 milligrams per day the pressure had risen to 160/88 by December 23. There was still no edema nor albuminuria. On February 8, as the situation was unchanged, 20 grains of calcium gluconate and 2 cubic centimeters per day of hytakerol were begun. On February 18 her pressure had fallen to 136/86. There was no edema nor albuminuria. However, her pressure began to rise again, and was 174/92 with a very faint trace of albuminuria on March 13. Her urine never showed calcium excess. On the 15th she was induced, and an 8 pound girl was delivered in (?) hours. At that time her blood pressure was 124/70. On March 23 there was a trace of albuminuria. On August 26 her pressure was 158/90. She has been well since.

Case 4. Mrs. W. B., aged 20 years, had her last period on November 10, 1943. It was her first pregnancy. When first seen on January 6, 1944, her pressure was 110/74, her urine clear and she had no edema. As her blood estrogen was positive she was given ephynal at once. By July 13 her pressure had risen to 138/88, there was some leg edema, she had a few uterine pains, and all this despite 4 capsules of mixed tocopherols(P.D.) per day. On August 3 there was a one plus albuminuria, her pressure had jumped to 146/106, there was much leg edema, moderate hydramnios, and therefore 20 grains of calcium gluconate and 3 cubic centimeters of hytakerol per day were begun. Five days later her edema was unchanged, but her albuminuria was only a very faint trace and her pressure had fallen to 140/98. On the 12th the pressure was 124/90 but the albuminuria was 2 plus. She went into labor spontaneously on that day and in 6 hours delivered a girl weighing 9 pounds 9 ounces. She

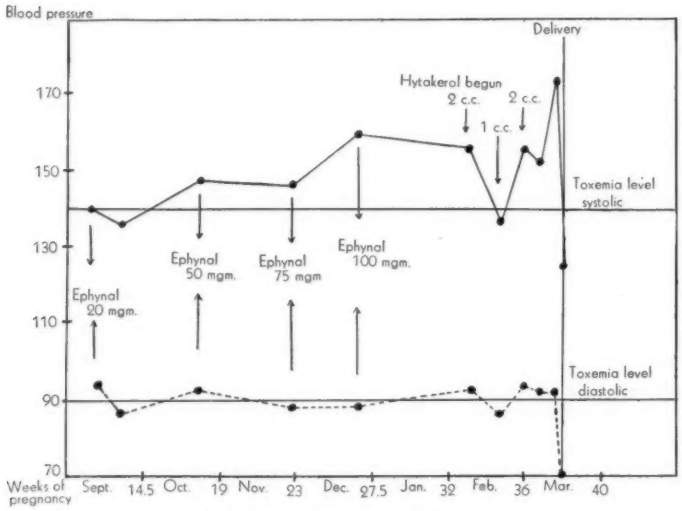


Fig. 3. Case 3. Mrs. D. K.

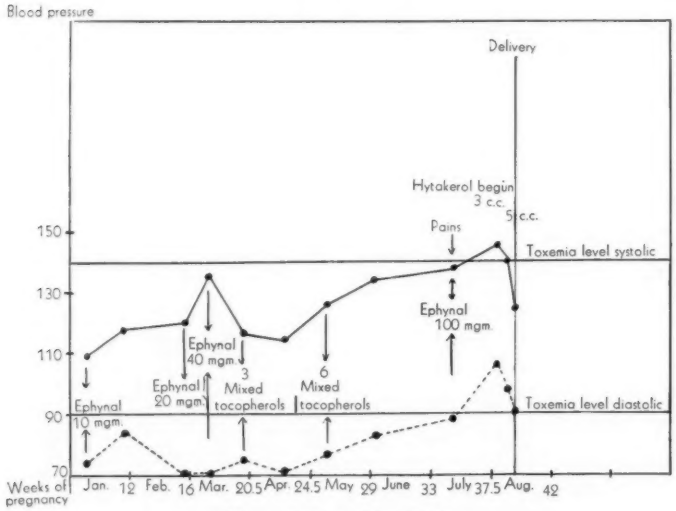


Fig. 4. Case 4. Mrs. W. B.

had an uneventful recovery. On September 29, 1944 her blood pressure was 118/90. She has been well since.

Case 5. Mrs. A. J. H., aged 31 years, had had two unexplained stillbirths at term. She wanted another child but her husband's sperm sample was very defective in both number and morphology. This semen was greatly improved by ephynal(14) and she promptly conceived. Her last period began on October 20, 1943. When first seen on November 30 she had a pressure of 166/108, although she had no albuminuria nor edema. Her blood estrogen being positive, she was put on a large dose of ephynal at once, and by December 11 the blood pressure had fallen to 156/88 Then she began to bleed slightly. Her ephynal dose was increased and the hemorrhage ceased. On February 12 her pressure had risen to 166/106. Therefore, her ephynal dosage was raised to 75 milligrams. Six days later her pressure was 134/96 and the urine was clear. On May 5 her blood pressure was 150/92, there was some leg edema, her urine was clear, and 2 cubic centimeters of hytakerol and 20 grains per day of calcium gluconate were begun. By June 1 her pressure had fallen to 144/84. On July 11 it was 146/90 with moderate leg edema and no albuminuria. Labor

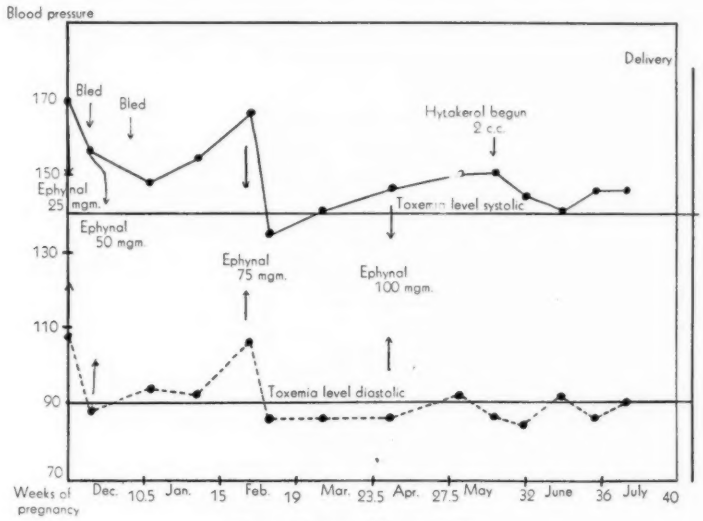


Fig. 5. Case 5. Mrs. A. J. H.

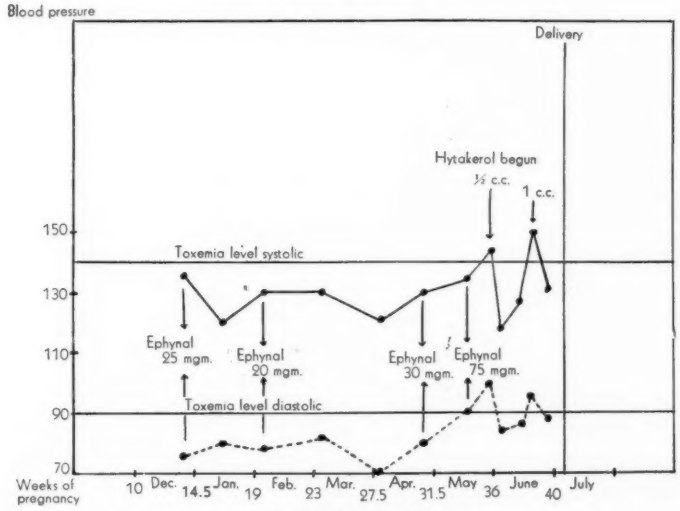


Fig. 6. Case 6. Mrs. R. L.

was induced on August 5 when her pressure was 146/96. A boy weighing 8 pounds 11 ounces was born in 8 hours. September 22, 1944, mother's blood pressure was 150/100, on January 6, 1945, 154/102. She has been well otherwise.

CASE 6. Mrs. R. L., aged 33 years, had her last menstruation on September 31, 1942. Previously she had had one toxic pregnancy, then two spontaneous abortions. When first seen on December 26, 1942 her blood pressure was 138/76, her urine was clear, she had no edema, but she was compelled to wear a pessary for uterine prolapse. As her blood estrogen was up she was given 10 milligrams of ephynal per day May 16 her pressure had risen to 134/90 despite 75 milligrams of ephynal per day. Her urine was clear and there was no edema. Twelve days later, on 100 milligrams, she showed 144/100, but still had no edema nor albuminuria. She was thenceforth given ½ cubic centimeter of hytakerol per day as well as 20 grains of calcium gluconate. A week later her pressure had fallen to 118/84. On June 19 the pressure rose suddenly to 150/96, there was minimal leg edema, but her urine was clear of calcium and albuminuria. The dose of hytakerol was doubled. In a week the pressure was down to 130/88. She was induced

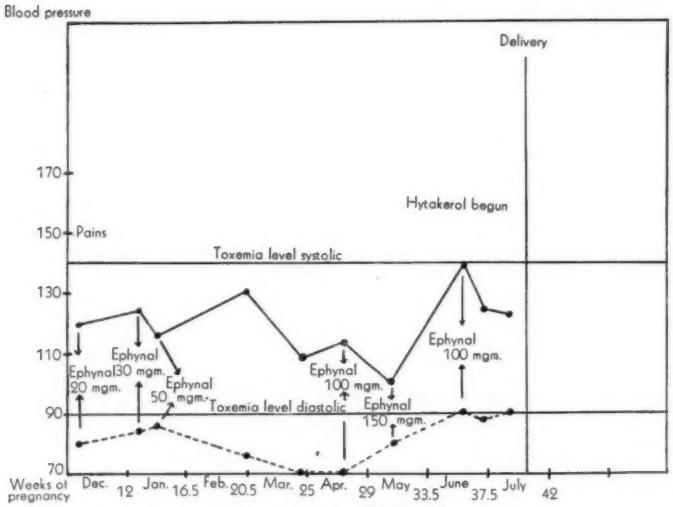


Fig. 7. Case 7. Mrs. J. W.

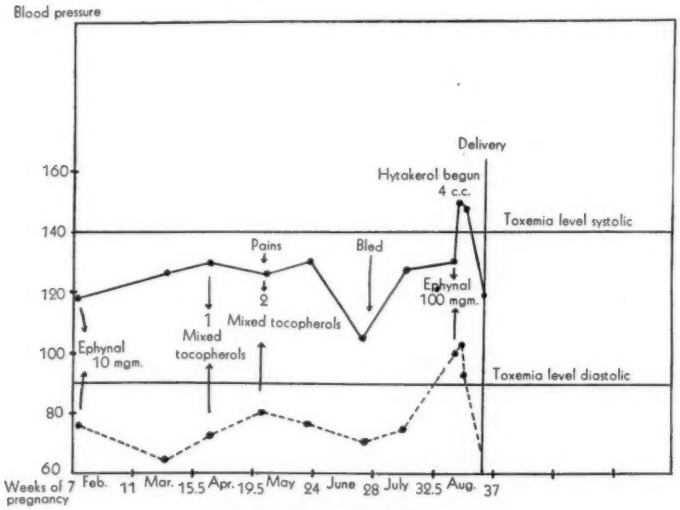


Fig. 8. Case 8. Mrs. W. S.

medically on July 8 and had an easy delivery in 2 hours of a girl weighing 7 pounds 12 ounces. The placenta was normal. Her blood calcium as labor began was 10.0 milligrams per cent. She has been normal since.

CASE 7. Mrs. J. W., aged 30 years, had a boy 5 years old and seemed unable to have another child. A lipiodol test showed complete bilateral tubal occlusion—but she conceived immediately! Her last period began on October 6, 1942, and when seen December 7 she had a pressure of 120/80, no edema or albuminuria, but did have slight, uterine distress. Because of this she was at once put on 20 milligrams of ephynal per day. As her pains continued this dose was gradually increased. On June 22 her pressure had risen to 140/90, with no edema, despite 150 milligrams of ephynal per day. She was therefore given ½ cubic centimeter of hytakerol and calcium gluconate grains 20 per day. In 7 days her pressure had dropped to 124/88 and her urine was clear. A week later her pressure was 122/90. On July 17 spontaneous labor delivered a normal girl of 7 pounds 8 ounces after a very easy labor of 2 hours. The placenta was normal. On October 16, 1943, her blood pressure was 98/70. She has been well since.

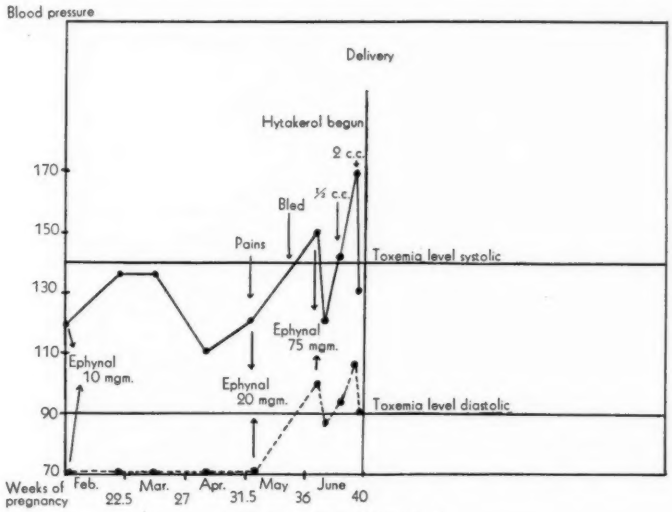


Fig. 9. Case 9. Mrs. A. J.

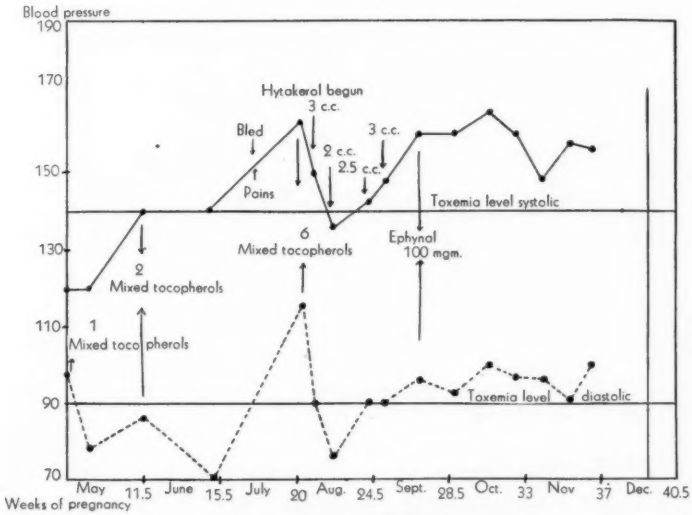


Fig. 10. Case 10. Mrs. W. S.

CASE 8. Mrs. W. S. aged 22 years, had her last menses on December 14, 1943. It was her first pregnancy. When first seen on February 3, 1944, she had a pressure of 118/76, no edema or albuminuria. As her blood estrogen level was up and she had had uterine pains she was given one capsule of mixed tocopherols(P. D.) per day. This was soon increased to 2 capsules per day, but after neglecting for a week to take any vitamin E she bled on June 30. However, vitamin E stopped this quickly. Suddenly on August 8 she exhibited a pressure of 130/100 and much leg edema, although her urine was clear. She was given 100 milligrams of ephynal per day thereafter with no obvious benefit. Therefore on August 10 she was given 4 cubic centimeters of hytakerol and 20 grains of calcium gluconate per day. In 5 days her pressure had fallen to 148/92. There was less edema but she showed a one plus albuminuria. The urine was negative for calcium. On August 22 labor began spontaneously, and she delivered a 5 pound 9 ounce boy in an hour. She had a blood pressure of 118/0 at this time, and catheter urine showed only a trace of albumin. Her blood pressure on August 24 was 130/70. Her condition has been normal since that time.

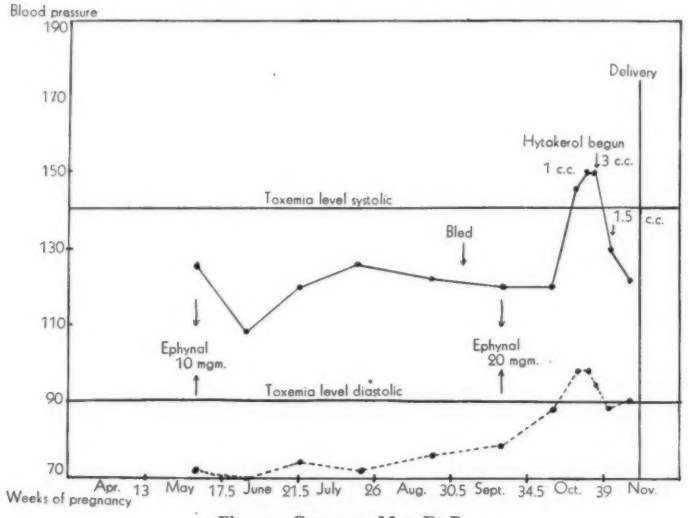


Fig. 11. Case, 11. Mrs. D. B.

Case 9. Mrs. A. J., aged 22 years, was first seen on February 2, 1943. She had had one normal pregnancy before. Her last period had begun September 17, 1942. At her first visit she had a pressure of 120/70, no edema or albuminuria. As her blood estrogen level was up she was at once given 10 milligrams of ephynal per day. She spotted blood on May 28. The daily dose was raised to 30 milligrams and bleeding promptly ceased. Despite this dosage the pressure suddenly jumped to 150/100 by June 8 with moderate leg edema and 3 plus albuminuria. Seventy-five milligrams of ephynal daily reduced the pressure to 120/86 in 7 days, cleared the urine, and decreased the edema. However, in another week the pressure was back to 142/94 and the edema was worse. Accordingly she was given ½ cubic centimeter of hytakerol and 20 grains of calcium gluconate per day. In 5 days her pressure had further risen to 170/106, but there was less edema and the urine was clear. Her dose of hytakerol was raised to 2 cubic centimeters and next day on admission to hospital for observation her pressure had dropped to 130/90. Her blood calcium then was 9.0 milligrams per cent. A medical induction brought on poor pains for a couple of days, but on the 27th of June a midforceps delivered a boy weighing 7 pounds 3 ounces after a 36 hour labor. Eight weeks later her pressure was 136/98. Later, on September 25, 1943, it was 136/76.

Case 10. Mrs. W. S. This patient, aged 31 years, had had three previous term deliveries. The first was a normal child, the last two were monsters. Her diabetic husband's temporary sterility had been promptly corrected with vitamin E, and she became pregnant at once. Her last period began March 13, 1944. At her first visit, 5 weeks later, her blood pressure was 120/98, her weight 175, and her urine was clear. Because of a high blood estrogen, she was given one mixed tocopherol capsule per day. Moderate vomiting developed and responded to testosterone propionate (13). Her pressure during the third month rose gradually to 140/100, then suddenly rose to 164/116 on August 4, 1944. Thenceforth she was given 100 milligrams ephynal daily, with an initial drop of blood pressure to 150/90 occurring after 4 days. Thereupon 3 cubic centimeters of hytakerol and 20 grains of calcium gluconate daily were also administered with a further rapid fall to 136/76 ensuing, and less edema. The hytakerol dosage was then decreased to 2 cubic centimeters daily and the pressure continued on an even level until it again rose suddenly 6 weeks later to 160/96, with a marked increase in weight. No edema was obvious, however, and her urine continued clear of albumin. During the subsequent 2 months, in spite of 100 milligrams of ephynal daily, the patient continued to gain weight rapidly, maintaining an almost constant blood pressure, varying between 150/96 and 166/100. Her urine remained negative, except for an occasional trace of albumin. On November 29 her blood calcium was 9.0 milligrams per cent. Following a medical induction of labor on December 19, 1944, she was delivered of a baby girl weighing 7 pounds 14 ounces. The placenta appeared normal. Her pressure during labor was 150/100, and when she left the hospital it was 130/88.

Case 11. Mrs. D. B., aged 32 years. This first pregnancy was dated from January 27, 1944. At that time her urine was clear, her blood pressure 126/72, and her blood estrogen test positive. She was accordingly given 10 milligrams of ephynal per day. On September 10 she spotted blood. Her dose of vitamin E was accordingly raised to 20 milligrams and the bleeding ceased promptly. On October 19 ankle edema developed and her blood pressure jumped to 146/98. She developed a sensitivity to ephynal and could take only a decreased dose thereafter. It was reinforced with 1 cubic centimeter of hytakerol per day, and 20 grains of calcium diphosphate therefore. No changes ensued. Hence the dose of hytakerol was increased to 3 cubic centimeters per day and the pressure promptly fell to 130/80 with decrease of edema. The Sulkowitch test on the urine was negative and remained so. There was no edema on November 9, and her pressure was 122/90, but there was a trace of albumin in the urine. Two days later labor began spontaneously but her pains were weak. Her membranes were artificially ruptured and then her labor proceeded normally with delivery of a normal girl weighing 7 pounds, 5 ounces. She has been well since.

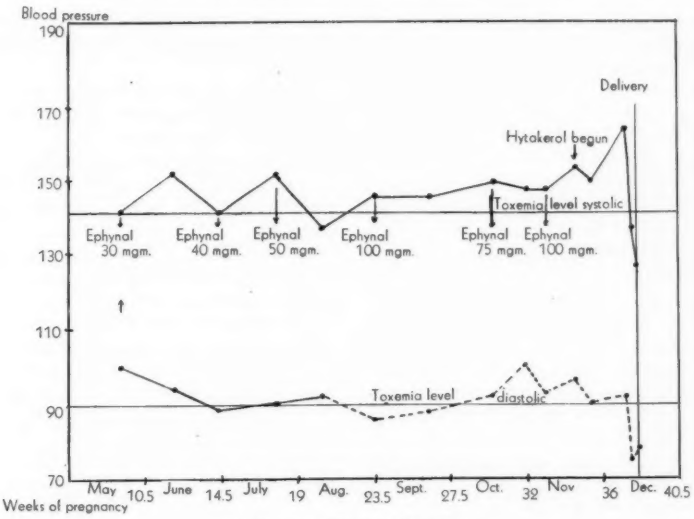


Fig. 12. Case 12. Mrs. E.

CASE 12. Mrs. E., aged 39 years, had delivered a macerated premature fetus in a previous toxic pregnancy. When first seen on April 24, 1944 she was 10 days overdue and having uterine pains. She was given 20 milligrams of ephynal per day, therefor. She spotted blood for a week early in May. On May 22 her blood pressure was 140/100, her urine clear, and she had no edema. Her blood estrogen was positive, and her dosage of ephynal was raised to 30 milligrams. On June 12 she had a slight bloody show with cramps, but her blood pressure was 150/94. She spotted again late in June and her vitamin E was then increased to 40 milligrams per day, her pressure then being 140/88. She bled slightly July 18 and her dose was then raised to 50 milligrams of ephynal. On September 1 her pressure was 144/86, there was no edema or albuminuria. Her dose of vitamin E was raised to 100 milligrams per day. On October 30 her pressure was back to 146/100, and she had slight bleeding but no edema. On November 20 her pressure was 152/96, she had no edema, and she was given 1½ cubic centimeters of hytakerol per day. On the 27th the pressure had fallen to 148/90. On December 8 it had risen again to 162/92, there was a minimal edema, no albuminuria, and she was admitted to hospital for observation and bed rest. On the 9th per pressure was 136/74 and on the 12th it was 126/78. She was delivered on December 13 of a normal male child weighing 7 pounds 13 ounces. On December 15 her blood calcium was 10.5 milligrams per cent. She has been normal since.

DISCUSSION

In this group of 42 refractory toxemia patients studied over the past 2 years, 16 or 38 per cent showed definite benefit on combined calcium and dihydrotachysterol administration, 14 per cent showed a slight or transient benefit, and 48 per cent were unimproved. The improvement was most evident in blood pressure but even a decrease of albuminuria and edema occasionally was noticed.

In the earlier cases of the series, dihydrotachysterol was given with extreme caution in an attempt to achieve the optimum level of blood calcium without elevating it dangerously. When small doses were thus used the improvement obtained was neither as immediate or decisive as in later patients of the group who were treated with larger amounts. In no instance, even when our highest dosage was employed, namely 5 cubic centimeters per day, did untoward symptoms develop. The maximum quantity of the synthetic hormone used was, it should be noted, considerably below that recommended for replacement therapy in the hypoparathyroid state. No cumulative effects were observed.

The advantages of the use of dihydrotachysterol in the pregnant woman are manifest. Its ability to increase the absorption and utilization of exogenous calcium spares the already menaced endogenous supply available in the bones and teeth. Hence it provides in these critical cases a much safer and more physiologic mode of therapy than the use of parathormone.

Most observers, employing calcium or parathormone or both in pregnant women, have remarked on the astonishing uniformity of blood calcium values during treatment, even with large doses of the hormone. It would appear that in normal and near-normal individuals, so stabilized is the equilibrium between conjugated and ionized

calcium, that to produce an elevation in blood calcium, an exceptional dosage is required. Moreover, as Klatskin points out, any excess of calcium or of phosphorus absorbed is excreted so rapidly that transitory variations in blood calcium level are rapidly leveled off. Reed states categorically that there need be little apprehension, for example, about administering amounts of parathormone up to 150,000 international units for indefinite periods of time.

How then does dihydrotachysterol combined with calcium affect the toxemias of late pregnancy? From the aforementioned findings, it appears that it leaves true pre-eclamptics clinically unchanged and benefits only some toxemic patients of the high estrogen group. Most women in this latter group respond fairly satisfactorily to the action of vitamin E, as we have shown elsewhere(15). But dihydrotachysterol is of great value in that important small fraction of the high estrogen late toxemias incompletely controlled in this manner by means of vitamin E.

No attempt is made at this time to explain the underlying mechanism of combined dihydrotachysterol and calcium therapy in the toxemias.

Its principle impact seems to be directed mainly upon the pressor factor. At least this treatment should be safer than parathormone in controlling the calcium factor in late pregnancy toxemias.

SUMMARY

1. The effect of combined dihydrotachysterol and calcium therapy is demonstrated on a series of 42 toxemias.

2. This therapy did not improve 4 true pre-eclamptics but definitely helped 42 per cent of 38 late toxemias of the high estrogen type which had not been controlled by vitamin E.

3. This differential response lends further support to our previous classification of the late toxemias.

4. This therapy appears to be most effective in lowering blood pressure, and less in the control of edema and albuminuria.

5. Variations in blood calcium level were small in this series, but the dose of dihydrotachysterol used was never more than 5 cubic centimeters per day.

6. This dosage is considerably below the level of replacement therapy in hypoparathyroidism and produced no toxic effects.

7. The use of dihydrotachysterol would appear to be a more physiologic and hence safer method of increasing calcium utilization in toxemic women than the administration of parathormone.

8. No explanation of the mode of action of this treatment is offered.

REFERENCES

1. Albright, F. J. Am. M. Ass., 1939, 112: 2592.
2. Albright, F., Sulkowitch, H. W., and Bloomberg, E. J. Clin. Invest., 1939, 18: 165.
3. Brougher, J. C. Am. J. Obst., 1942, 43: 110.
4. Daly, A. J. Obst. Gyn. British Empire, 1933. 40: 209.
5. Klatskin, G. J. Clin. Invest., 1938, 17: 431.
6. Lopez, R. E. Surg. Gyn. Obst., 1929, 49: 689.
7. Mendenhall, A. M., and Drake, J. C. Am. J. Obst., 1934, 27: 800.
8. Mitchell, J. R. Med. Red., N.Y., 1910, 78: 906.
9. Morel, L., and Rathery, F. J. physiol. path. gen., 1912, 14: 901.
10. Reed, C. I. J. Am. M. Ass., 1934, 102: 1745.
11. Richardson, G. C. Illinois M. J., 1931, 59: 453.
12. Shute, E. V. Surg. Gyn. Obst., 1937, 65: 480.
13. Idem. Am. J. Obst., 1941, 42: 490.
14. Idem. Urol. Cut. Rev., 1944, 48: 423.
15. Idem. J. Obst. Gyn. British Empire in press.
16. Theobald, G. W. Lancet, Lond., 1937, 232: 1397.

"EARLY RISING," FOLLOWING MAJOR SURGICAL OPERATIONS

PAUL W. SCHAFER, M.D., and LESTER R. DRAGSTEDT, M.D., Chicago, Illinois

"EARLY rising" of patients after major operative procedures has, since the enthusiastic report of its first advocate in 1899 (4), attracted the attention of many surgeons. A recent review by Newburger adequately summarizes their observations. Interestingly enough, those who have given this principle an extensive trial have, almost uniformly, been favorably impressed and many have loudly acclaimed its virtues. In general, critics of the practice have self-admittedly had little experience with it and have based their criticism on one or a few unfortunate complications which may or may not have been justifiably attributed to early rising. In spite of the fact that the medical literature, mainly European, contains reports of many thousands of favorable cases it is only in the past few years that any significant amount of attention has been given the subject in this country. This seeming paradox exists because early rising of patients after operation is the exact contradiction of one of the most deeply rooted principles of patient care. Early rising of patients with early and rapidly increasing ambulation together with coughing and breathing routines is not here being advocated as a substitute for, but as an adjunct to, the generally accepted and proven features of surgical technique and preoperative and postoperative care. Indeed, early rising is now possible only because of improvement in surgical technique with gentle handling of tissues, accurate reconstruction of wounds, strict asepsis and antisepsis, adequate general and local preoperative preparation, good anesthesia, prophylactic and definitive decompression of the stomach and intestines, restoration and maintenance of fluid balance and recognition of the importance of blood and plasma loss which must be replaced by adequate transfusion. Undoubtedly, in the past, attempts at early rising and ambulation of patients occasionally met with failure because the care of the patient was otherwise inadequate.

It was with considerable hesitation that we began to test the principle on patients who had had some of the larger surgical procedures.

From the Department of Surgery of the University of Chicago. Aided in part by a grant from the Douglas Smith Foundation.

The first case was that of a 68 year old female with a large carcinoma of the hepatic flexure of the colon. After adequate preoperative hydration and blood transfusion the patient was explored through a long right paramedian incision. The tumor mass was found to be firmly adherent to the duodenum and the head of the pancreas but, since all of the visible tumor was in continuity and no remote metastases were seen, a resection was done. This necessitated an *en bloc* removal of the right colon, all of the duodenum, part of the stomach and the head, neck, and part of the body of the pancreas. Reconstruction consisted of an ileotransverse colostomy, cholecystjejunostomy, and gastrojejunostomy. The abdomen was closed without drainage. The operation was carried out under continuous spinal anesthesia and lasted 4 hours. Blood and saline were administered throughout the operation. Continuous Wangensteen suction of the stomach was begun immediately after operation and was continued for 48 hours. The patient's general condition remained good but on the day following operation the posterior lung fields at the base were dull, breath sounds were suppressed, and râles were present. Respiration was of poor character. It was felt that the patient would likely develop a serious pulmonary complication if the ordinary regimen was followed so, on the second postoperative day, she was removed from the bed and allowed to stand on the floor and to sit in a chair for 15 minutes. Coughing and deep breathing were encouraged. Her cough was productive of a limited amount of white, frothy mucus, and examination of the lung fields revealed full aeration with disappearance of the basal râles. Respirations were of greatly improved quality. Rapidly the patient's time away from the bed was increased and by the sixth day she took twice daily strolls up and down the corridor. Her maximum temperature elevation was 100.8 degrees F., and was recorded on the third postoperative day. By the fifth day her temperature was normal and remained so until the time of discharge from the hospital 20 days after operation. This long hospital stay resulted more from the interest of the staff than from the requirements of the patient.

Soon after this favorable experience more and more patients were subjected to the same routine. Since enthusiasm mounted, within 2 months all patients on the service were out of bed on the second postoperative day. The 102 cases summarized in Table I represent the basis for this report.

As may be seen in Table I, the series includes most of the usual general surgical operations. It is made up of patients who, without selection, presented themselves for surgical care from February to September, 1944. Since October 1, 1944 many more patients have experienced early rising but are not included in this communication. The general management of these patients and

TABLE I.—SUMMARY OF POSTOPERATIVE OBSERVATIONS ON PATIENTS EXPERIENCING "EARLY RISING" FROM FEBRUARY TO SEPTEMBER, 1944

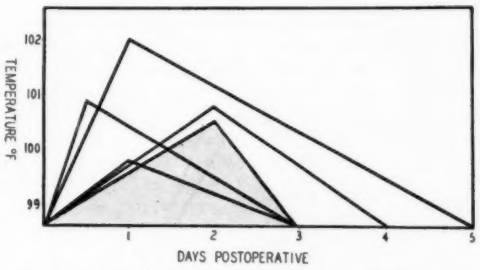
	Number of cases	Age	Day of rising	Day of discharge	Temperature		
					Maximum elevation		Day of return to normal
					Day	Level	
Inguinal herniotomy	11	41	1.7	9	0.6	99.5	1.3
Incisional herniotomy	6	57	2.0	9	1.2	100.7	4.5
Epigastric herniotomy	3	41	1.0	6	1.0	99.7	1.7
Femoral herniotomy	1	30	2.0	9	0.0	98.6	0.0
Appendectomy (acute)	15	32	2.0	6.6	1.0	99.7	2.0
Appendectomy (chronic)	4	29	1.7	6.2	1.0	99.7	1.8
Cholecystectomy	13	45	2.5	9.6	1.5	100.6	3.2
Radical mastectomy	5	54	2.0	7.7	0.8	101.0	2.7
Subtotal gastrectomy	9	52	2.7	10.7	2.8	100.9	4.9
Total gastrectomy	2	51	2.5	12.5	4.5	100.9	6.0
Subtotal thyroidectomy	5	39	2.6	5.8	1.0	100.6	3.0
Partial thyroidectomy	4	38	1.2	5	0.8	99.7	2.7
Transthoracic vagotomy	8	36	1.7	13.0	1.2	101.2	4.6
Gastro-jejunostomy	3	42	2.0	9.7	1.0	99.9	2.0
Right colectomy	3	52	2.3	12.0	2.0	100.5	3.0
Resection of sigmoid colon	2	54	2.0	12.0	3.0	101.2	4.0
Cholecyst-gastrostomy	1	84	3.0		1.0	100.0	2.0
Gastro-duodenostomy	1	57	2.0	11.0	2.0	100.0	3.0
Abdomino-perineal resection of rectum	1	73	3.0	8.0	2.0	101.0	3.0
Right colectomy and pancreato-duodenectomy	1	68	2.0	20.0	3.0	100.8	5.0
Colostomy	1	40	1.0	9.0	2.0	101.0	4.0
Closure of colostomy	1	55	2.0	9	2.0	100.0	3.0
Choledochostomy	1	39	2.0	11.0	1.0	100.4	3.0
Cholecystostomy	1	63	2.0	14.0	1.0	100.6	2.0
Total number of cases	102						

specific surgical techniques were in no way altered with the institution of this program. Abdomens were operated on through a variety of incisions with oblique and transverse approaches being most commonly used. All peritoneal sutures were of a continuous type, usually a double strand of either No. oo or No. o chromic gut being used. Closure of the fascia was usually made with a continuous suture of either No. oo or No. o chromic gut re-enforced with interrupted sutures of No. o chromic gut placed 2 to 3 centimeters apart. Interrupted No. ooo plain gut sutures were used for the subcutaneous fat and continuous black silk for the skin. A gridiron incision was routinely used for appendectomy. Hernia repair followed the general pattern just indicated. No abdominal support was routinely used although in cases which were likely to require frequent dressing, an adhesive type corset was employed. Early rising was begun at some time during the first or second postoperative day and rapidly increased thereafter.

It is difficult to convey the extremely favorable impression which has been made on us by this radical departure from a firmly entrenched routine of postoperative care. This difficulty lies chiefly in the fact that the benefits which result are of a nature which do not easily lend themselves to conversion into letters, numbers or symbols, which may be charted or made into graphs, and a general description is an inadequate substitute for the experience of observing these patients. They possess an excellent morale which improves day by day as they are freed from the burden of apprehension, fear and imagined complications which are so apt to beset a person not

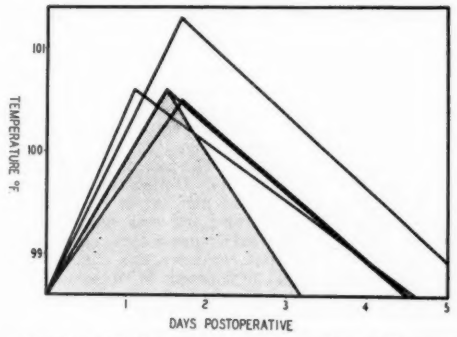
familiar with the ways of medical practice. Because of early exercise the marked weakness felt by the patient who leaves his bed on the tenth or twelfth postoperative day is greatly minimized. Early rising allows the patient to take over the management of his own personal hygiene at an early period and thus greatly reduces his nursing requirements. In this series, patients have not been discharged from the hospital as early as their condition would have permitted since an opportunity to observe them closely was desired. However, their hospital stay can be materially shortened as a result of early rising. This represent a financial saving to the patient and because of the more rapid turnover, allows hospital care for a larger number of patients with existing hospital facilities.

Probably the most important result of early rising is the prevention of many minor and major pathological pulmonary changes. Following operations within the abdomen, especially procedures in the upper abdomen, and as a result of maintenance of the horizontal position, the diaphragm is reflexly inhibited and assumes an abnormally high position. This factor results in basal pulmonary atelectasis with all of its hazardous potentialities. Clinically, this condition is evidenced by shallow, rapid respirations, increased pulse rate, basal suppression of breath sounds, dullness, and râles. These changes have been observed so constantly in the first few postoperative days that they have become accepted as the normal postoperative course and all surgeons are familiar with the postoperative "hump" in the *TPR* curve. Leithauser has shown that with early rising the vital capacity returns to normal in half the time required by the bed-confined postoperative patient (1).

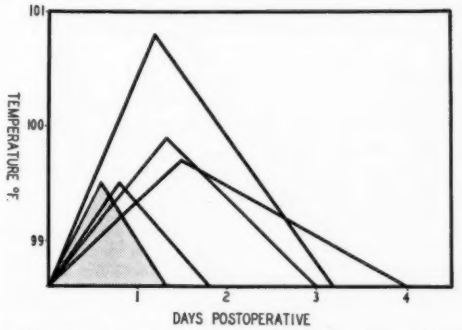


Graph 1. Right colectomy. Comparison of the average postoperative temperature record of a group of "early rising" patients with those of the bed confined patients of four other general surgical services. The solid black line enclosing the shaded area of the graph represents the average postoperative temperature record of the "early rising" patients.

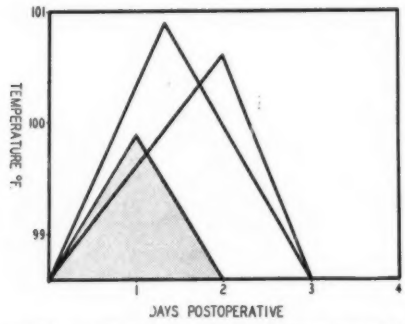
In this study the problem was approached by a comparison of the postoperative temperature records of early rising patients with those of bed confined patients. Forty early rising patient's records were compared with those of one hundred bed confined patients cared for by the four other general surgical services of the clinics. The results may be seen in the accompanying graphs (Figs. 1 through 5). In practically every instance the early rising patients had a lower maximum temperature elevation and resumed a normal temperature level sooner than did the bed confined patients. Clinically this freedom from prolonged fever was closely correlated with improve-



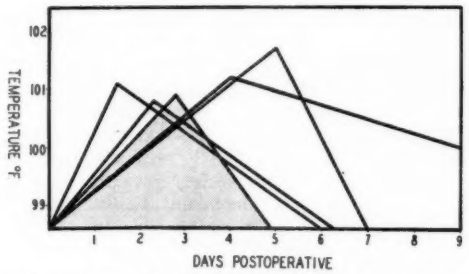
Graph 2. Cholecystectomy. Comparison of the average postoperative temperature record of a group of "early rising" patients with those of the bed confined patients of four other general surgical services. The solid black line enclosing the shaded area of the graph represents the average postoperative temperature record of the "early rising" patients.



Graph 3. Inguinal herniotomy. Comparison of the average postoperative temperature record of a group of "early rising" patients with those of the bed confined patients of four other general surgical services. The solid black line enclosing the shaded area of the graph represents the average postoperative temperature record of the "early rising" patients.



Graph 4. Gastrojejunostomy. Comparison of the average postoperative temperature record of a group of "early rising" patients with those of the bed confined patients of two other general surgical services. The solid black line enclosing the shaded area of the graph represents the average postoperative temperature record of the "early rising" patients.



Graph 5. Partial gastrectomy. Comparison of the average postoperative temperature record of a group of "early rising" patients with those of the bed confined patients of four other general surgical services. The solid black line enclosing the shaded area of the graph represents the average postoperative temperature record of the "early rising" patients.

ment in the character of respiration. Others have claimed for this routine a lessened incidence of thrombophlebitis, phlebothrombosis and embolism (2) but since these complications are relatively rare in this area, no valid information can be obtained from this series in which none of these complications was observed. It may be that early rising would represent an adjunct to or, possibly a substitute for, vein ligation which is practiced in the Atlantic and Gulf seaboard states in which localities these complications are common.

Almost the only consistent criticism of early rising is that it might mechanically damage the wound and result in delayed healing, postoperative herniation or dehiscence. From observations made on these 103 patients there is no basis for such criticism. In the entire series only four significant complications have been encountered. Two were fatalities and two were late herniations, and in no case is there good evidence that the same complications would not have occurred if early rising had not been carried out. No significant pulmonary complication occurred in any one of the 103 cases.

CASE 1. D.V., a 73 year old male, underwent a combined abdominoperineal resection of the rectum for carcinoma on September 22, 1944, the sigmoid colostomy being established in the center of the low left paramedian incision. He had marked postoperative distention and respiratory distress and was intermittently irrational. Management was extremely difficult. He was helped out of bed on his second postoperative day and the early rising program continued from this time. His respiration was moderately improved and he was afebrile by the third day but his distention persisted and the colostomy did not function. On the morning of the fifth day he became restless and pulled out his gastric suction tube. During replacement of the tube by the interne the patient coughed violently and experienced severe pain in the abdominal wound. Examination revealed that a disruption had occurred in the superior portion of the incision. Within the hour the wound was re-sutured. His condition rapidly deteriorated. His ileus persisted, the distention increased, he became more febrile, weaker, and finally died 3 days after breakdown of his wound. Postmortem examination revealed a generalized peritonitis. What effect early rising had on the wound dehiscence and eventual death is problematical since the same complications have been observed in bed confined patients under similar circumstances. However, this wound, containing a colostomy, was not mechanically as strong as if it had been completely closed and the colostomy brought out through a separate incision.

CASE 2. B.H., a 45 year old female, entered the hospital June 8, 1944, complaining of nausea and vomiting continuously for the previous 4 days. On physical examination the patient was found to be in shock with marked carpopedal spasm. She gave a history of having had a carcinoma of the descending colon resected in March, 1943. The clinical impression was that she had alkalosis with tetany due to vomiting caused by obstruction of the duodenum or stomach as a result of probable recurrence of carcinoma. Because of persistent obstruction and, after what seemed to be adequate preparation, she was operated on June 26. A large retroperitoneal recurrence was found to be obstructing the duodenum so an anterior gastroenterostomy was performed. Her early postoperative course was uneventful and early rising was begun on the second postoperative day and continued. The patient was afebrile by the afternoon of the third day. During the night of the fourth day and again on the morning of the fifth postoperative day, without warning and while lying quietly in bed, the patient experienced sudden attacks characterized by cessation of respiration, cyanosis, and coma. On examination no pulse could be palpated. With the first attack oxygen was administered and she soon recovered completely but with the second attack death quickly occurred. Postmortem examination was not permitted. Clinically she was felt to have had a Stokes-Adams syndrome and again its relation to early rising is a matter for conjecture.

CASES 3 AND 4. All of the patients in the series have been closely observed for the late development of hernias. To date this complication has occurred twice. Both of the patients were men operated on in July 1944, and in each case the first sign of herniation was observed in the fourth

postoperative month. One of the patients had a cholecystectomy through a high right oblique incision and the other had a subtotal gastrectomy through a long upper left oblique incision. In the former a drain was brought to the outside through the line of incision and in the latter a localized superficial wound infection developed. Herniation in each case was at the site of local weakness in the wound.

SUMMARY

In summary, the early rising of 103 general surgical patients has been observed and has resulted in a uniformly favorable impression of the practice. Improvement in the general well-being of these patients over that of bed confined patients has been discussed. With early rising there is improved morale, avoidance of asthenia, more patient self-care and less nursing care, less financial loss to the patient because of shorter hospitalization and earlier rehabilitation, and, because of more rapid turnover, more patients can be cared for with existing hospital facilities and personnel. Early rising patients have been shown to have a lower postoperative fever of shorter duration than the bed confined patients of four other general surgical services. This factor in our opinion is closely related to observed improvement in respiration. The record of complications presented here compares favorably with the number of complications observed in a similar group of bed confined patients.

REFERENCES

1. CHURCHILL, E. D., and MCNEIL, D. Surg. Gyn. Obst., 1927, 44: 483–488.
2. LEITHAUSER, D. J. Arch. Surg., 1943, 47: 203–215.
3. NEWBURGER, B. Surgery, 1943, 14: 142–154.
4. RIES, E. J. Am. M. Ass., 1899, 33: 454–456.

EDITORIALS

SURGERY
Gynecology and Obstetrics

FRANKLIN H. MARTIN
Founder and Managing Editor
1905–1935

LOYAL DAVIS, EDITOR

Associates
SUMNER L. KOCH MICHAEL L. MASON

DONALD C. BALFOUR, *Associate, Editorial Staff*

JULY, 1945

1905–1945

THIS issue marks the beginning of the forty-first year of SURGERY, GYNECOLOGY AND OBSTETRICS founded in 1905 by Franklin H. Martin. It was his conviction that there was a real need for a surgical journal which should appeal to practical surgeons, to be edited by active surgeons, the profits from which should be utilized in strengthening its worth and influence.

He was aided by a small group of young surgeons who had been intimately associated with him in the course of their surgical training, by Mr. T. E. Donnelley, of R. R. Donnelley & Sons Company, a friend of long standing, and a nucleus of men and women who have loyally and conscientiously carried out the many-sided tasks of great magnitude which are so vital to the success of such a publishing venture. The unfailing interest and enthusiasm of this original group who believed in Dr. Martin's dream, and their steadfast devotion to the ideal of creating a surgical journal second to none, which was firm within the heart of each of them, are responsible for the success of SURGERY, GYNECOLOGY AND OBSTETRICS. The direction of its business affairs, the assembling and composition of the material presented, the quality of its typography and reproductions, the conduct of the daily affairs of this journal have all represented throughout these years the contributions of the personalities chosen to carry out these many activities. It has been their gifts throughout the years which have made of this journal more than an ordinary commercial enterprise.

The editorial policy from the first was created and carried out by Allen B. Kanavel whose idea it was that the journal should constitute a forum wherein the ideas and accomplishments of men in the surgical world could be presented without any imposition whatever of the beliefs or opinions of the editors. The journal vouched for the honesty and sincerity of the authors whose work it published but left for its readers and time to establish the correctness of their views. All editorial comments and book reviews have always been published over the signature of the author upon the basic principle that the reader has a right to know the source and may assume that what he reads is a well-considered statement of opinion.

With Mrs. Martin's death, the direction of SURGERY, GYNECOLOGY AND OBSTETRICS passed into the hands of the Board of Regents of the American College of Surgeons, another of her husband's contributions to the surgical progress of this country. The journal will continue to attempt the fulfillment of Dr. Martin's conception of a surgical journal and will devote its pages to the contributions of prac-

tical surgeons, edited by active surgeons, with any and all profits derived from its circulation and advertising matter utilized for the creation of an increasingly better production.

LOYAL DAVIS

SUBDURAL HEMATOMA

SUBDURAL hematoma was once considered a rare condition and of only pathologic interest. Actually it is one of the important indications for surgical intervention after craniocerebral trauma. Virchow originated the concept that subdural hemorrhage was secondary to some inflammatory process of the dura and gave it the name "pachymeningitis interna chronica." Numerous reports have presented various etiologic causes; notably lues, alcoholism, scurvy, and infectious diseases. It was not until Trotter's report in 1914, that the condition became of interest to surgeons.

Contrary to the concept that inflammation is the primary etiologic factor is the concept that the primary lesion is a hemorrhage. The hemorrhage is not necessarily traumatic. Russel and Cairns reported four cases of carcinomatosis and sarcomatosis of the dura with formation of a subdural false membrane. Neoplasm or vascular malformation may be a predisposing factor. The writer has had a case of subdural hematoma overlying a glioblastoma of the temporal lobe and another overlying a venous angioma in the same location. Both of these patients had suffered a mild head injury before the onset of any symptoms referable to an intracranial lesion.

An essential question is the primary location of the bleeding—whether subdural or intradural. Baker, Hannah, Kaump and Love have presented histologic evidence to indicate the intradural origin of these hemorrhages. On the other hand Leary pointed out that in the early stages of encapsulation of free blood in the subdural space, the neomembrane or capsule forms first on the dural side and later on the arachnoid side, and that the neomembrane on the dural side is always in a more advanced stage of development than on the arachnoid side. Surgical observations on subdural hematomas in various stages of development substantiate Leary's statements.

The mechanism of the progressive enlargement of the clot is a matter of considerable dispute. All are agreed that there is progression in the development of the clot. Massive acute subdural hemorrhage does occur in extensive injury (laceration) of the brain. These cases have early and marked symptoms and usually result fatally. The onset of the subacute or chronic case is slower and often insidious. The initial brain injury is relatively insignificant or, if more severe, the patient recovers from it.

Gardner, Leary, Munro, and others have assumed that the initial lesion is the escape of blood into the subdural space. As the result of a fall or a blow to the head the brain is displaced in the cranial cavity. This may cause tearing of a vein crossing the subdural space. Recently this has been demonstrated experimentally in the monkey by Craig, Sheldon, and Pudenz, who have been able to take motion pictures through a lucite calvarium of such a hemorrhage following a subconcussive blow to the animal's head. Usually it is a superior cerebral vein that is torn but inferior veins to the sphenoparietal or transverse sinuses may be torn. In any case rupture of a vein as it crosses the subdural space allows the escape of blood into that space. The venous pressure in the cerebral veins is low, and the bleeding usually soon stops spontaneously. As liquefaction of the blood in the subdural space begins the resultant fluid is high in protein content. Since it is separated from the subarachnoid space by only the arachnoid (and

later the newly developing neomembrane on the arachnoid side), and since this is impervious to the large protein molecules in the liquefying blood, an osmotic imbalance must exist between the cerebrospinal fluid and the liquefying blood with resultant passage of fluid into the subdural space. As time goes on and the hemoglobin molecules begin to break down, there is a great secondary increase in molecular concentration following the breaking down of the large protein molecules. Consequently, there is a late secondary tendency to increase in size of the clot. The dura reacts early to the presence of the blood in the subdural space, and a neomembrane or capsule forms first on the dural side. Later a more gradual reaction of the arachnoid produces a neomembrane on the arachnoid side of the clot.

Most subdural hematomas are on the lateral aspect of the hemisphere; some are inferior and anterior, others posterior and inferior. They are progressive expanding lesions and must be treated surgically. A burr hole in the parietal region above the ear will disclose practically every clot. Most of them can be satisfactorily evacuated through single or occasionally multiple burr holes; only rarely is it necessary to reflect an osteoplastic flap. Since the clots are often (12 to 15%) bilateral, a burr hole should be made on each side in every case.

In 75 consecutive patients who were operated on a history of trauma was present in all but three. At times the trauma is so slight that it is overlooked by the patient, particularly if a considerable time interval intervenes between the trauma and the appearance of the symptoms. This interval may be brief or it may range up to several months. Time intervals of a year or more raise the question of a second later, but forgotten, injury.

Mental disturbance is the most outstanding clinical symptom and was noted in over 90 per cent of the cases. The picture is usually one of progressive confusion finally advancing to stupor or coma. Very often the condition fluctuates markedly. One day the patient is grossly confused or stuporous, the next relatively alert. Occasional dramatic recoveries from apparently terminal coma may be stimulated by administration of a hypertonic solution of glucose or sucrose intravenously or by spinal drainage. Unfortunately if the true condition is not recognized the physician is lulled into security but soon the patient lapses into a stupor that is permanent and ends fatally.

Neurologic abnormalities in the form of hemiparesis or paralysis, abnormal reflexes or some degree of aphasia are very frequent. These findings often do not appear until late in the development of the condition. Headache, dizziness, or nausea and vomiting are common.

The spinal fluid is xanthochromic in two-thirds of the cases. Clear spinal fluid does not rule out the presence of a hematoma or even make it improbable but xanthochromic fluid usually indicates the diagnosis. However, subarachnoid hemorrhage is often present in brain injury and, if the antecedent trauma precedes the spinal puncture by less than two weeks, the xanthochromia has to be disregarded. Observation of the spinal fluid findings in a large number of cases of traumatic subarachnoid hemorrhage has convinced us that the spinal fluid will be clear within 12 to 14 days after a brain injury.

Papilledema is found in one-half of the cases. Convulsions, often Jacksonian, sometimes generalized, are seen nearly as often as in tumors near the central sulcus. Occasional bradycardia with a pulse rate below 60 is present in many cases. It is seldom persistent,

only recurrent, and often is noted only by reviewing the hospital chart over a period of several days.

Subdural hematoma, during the past thirty years, has come to be recognized as an important post-traumatic surgical complication. Many cases are still unrecognized. The surgical profession should be more aware of this condition and realize that often it can be recognized only by the exploratory burr hole. In any suspected case bilateral posterior parietal burr holes should be made. If no clot is found little harm will be done by this procedure which entails mimimal operative shock and can easily be done under local anesthesia, supplemented by intravenous anesthesia if the necessity arises for such a procedure.

HAROLD C. VORIS

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

THE fourth edition of *Combined Textbook of Obstetrics and Gynecology*[1] written by Munro Kerr and others of Glasgow, Edinburgh, and Aberdeen, Scotland. The first edition was published in 1923 in an attempt to correlate more closely obstetrics and gynecology. This was the first book to attempt to so do. Through all the editions including the current one the authors have emphasized the indivisibility of the two sciences, and have expressly attempted to impress the medical student with the importance of a thorough knowledge of obstetrics and with the fact that a great many ailments encountered in gynecological practice are the result of infections and injuries contracted during parturition. A short chapter is devoted to connecting the two sections of the book and in emphasizing their interrelation.

The book *in toto* is just short of 1200 pages, roughly two-thirds of which are devoted to obstetrics and one-third to gynecology. It is written in large print on smooth paper, is excellently bound, and makes for easy reading. There are 511 illustrations and numerous x-ray plates. There are illustrations in color for the first time in this edition some of which appear in the section on anatomy and are taken from Cunningham. Although the illustrations are numerous, many are schematic and diagrammatic, lacking strength of detail and warmth.

Although there have been important alterations over previous editions in the chapter on analgesia and anesthesia because these subjects have been so much in the limelight in recent years, there is no discussion of the currently popular continuous caudal anesthesia. Modern treatment of gonorrheal infection with sulfonamides is detailed but more recent developments in penicillin therapy are not included. The recent work on the Rh factor has been incorporated in the chapter on complications in the third stage of labor in which blood transfusion is considered. There have been additions to the chapter dealing with the health, nutrition, and disorders of the newly born infant. Inasmuch as the authors have especially written this textbook for medical undergraduates, and inasmuch as they do not consider that minute details of surgical technique should form part of the training of such students, there is a relatively scanty space allocated to major gynecological surgery. On the other hand there is a very full and adequate consideration of functional disorders, especially infertility. Here reference is made to contraception for the first time and its limitations defined.

All in all one is impressed with the logical and interesting way in which the authors have organized this extensive subject matter. The book is well written and certainly ranks among the leaders in its field. Perhaps it is the foremost single volume work on the combined specialties. STUART ABEL.

ONE has the impression that Comroe's *Arthritis and Allied Conditions*[2] was written by a man who is enthusiastic about his subject and who wants to make his subject matter useful to the *entire* medical profession. The data are detailed and specific on every subject, but in each chapter summaries of the important points are presented for the hasty reader. A tremendous medical literature on arthritis, rheumatic fever, fibrositis, gout, internal derangements of the knee joint, low back pain, etc., has been reviewed and the references cited. Specialists in the field of arthritis should be interested in this feature. However, the book is in no sense simply a compendium of the available knowledge. It represents an honest effort to give practical information to the man caring for arthritis patients and to debunk such questionable procedures as massive vitamin D therapy and to define the somewhat narrow fields of usefulness and limits of safety for gold salt therapy, iontophoresis, vaccine therapy, etc. On the controversial points both sides of each question are presented and documented, but the reader is never left in doubt as to the author's viewpoint.

Of special interest to surgeons will be the chapters on painful shoulder, Dupuytren's contracture, painful feet, backache and tumors of joints and tendon sheaths. In the chapter on "Mistakes in the diagnosis and handling of patients with arthritis and allied conditions," 238 errors are listed, many of which are of very common occurrence among men of excellent training.

To those who want to care for patients with arthritis more intelligently the book is highly recommended. PAUL S. RHOADS.

A THOROUGH review of all forms of anesthesia, analgesia, and amnesia used in the management of obstetric conditions is presented in *Control of Pain in Childbirth*.[3] It is generously illustrated with colored plates and contains numerous pharmacologic charts which show the effects of the drugs on both the mother and the baby.

[1] COMBINED TEXTBOOK OF OBSTETRICS AND GYNECOLOGY. Revised by J. M. Munro Kerr, LL.D., M.D., F.R.F.P.& S., F.R.C.O.G. Baltimore: The Williams & Wilkins Co., 1944.

[2] ARTHRITIS AND ALLIED CONDITIONS. By Bernard L. Comroe, A.B., M.D., F.A.C.P. Philadelphia: Lea & Febiger, 1944.

[3] CONTROL OF PAIN IN CHILDBIRTH. By Clifford B. Lull, M.D., F.A.C.S., and Robert Hingson, M.D. Philadelphia, London, Montreal: J. B. Lippincott Co., 1944.

The book is 338 pages in length and is well indexed and subdivided so that the reader can easily and quickly refer to any portion of the subject. The material is presented in three parts.

The first part deals with the anatomy of the female reproductive system and the physiopharmacology of the agents used to control pain. This division also includes some very timely remarks on the psychology of the management of pregnancy and labor.

Part II reviews the history of the relief of pain during childbirth from the early civilizations to the present time. Then the techniques of administration of the various pain-killing agents are considered. Caudal anesthesia is treated in great detail, and the authors leave no doubt in the mind of the reader that it is their preference. They do, however, give a balanced and fair discussion of the contraindications and hazards of caudal anesthesia.

Pain relief in cesarean sections and in home deliveries is considered. The effects of the pain relieving agents are also shown in relation to the management of the third stage of labor and in relation to the management of the puerperium.

Part III is devoted to the control of pain when various maternal complications are present and to the methods and drugs which are used in the resuscitation of the newborn.

In the preface we are told that an attempt is being made to establish "a bridge of communication between the specialty of anesthesiology on the one hand and the specialty of obstetrics on the other." The authors have succeeded in accomplishing this end in a very scholarly and at the same time readable manner. This book is highly recommended for the student, the specialist, and the general practitioner.

AUGUSTA WEBSTER.

A COMPILATION of opinion concerning the treatment of common diseases is presented in a highly personalized manner in the *Textbook of Surgical Treatment*[1]. There are nineteen contributors, including the editor, Mr. Illingworth. Details of certain minor and emergency operations are given, but major operations and highly specialized procedures are considered in rather general terms. Being "intended mainly for senior students and those undergoing training in surgery," the book is remarkably devoid of references to pertinent recent clinical and laboratory observations. There is no bibliography or list of references, and allusions in the text to sources or to other authors are few and far between. Many recent contributions and advances in surgery are neither discussed nor taken into account.

The chapter on treatment of burns, although referred to in the preface as the most notable change to be found in this second edition, is in fact a poor treatise on the subject. The book is altogether too incomplete and outmoded to excuse its publication in 1944. The index is inadequate, even for the material included.

AMBROSE H. STORCK.

AN excellent reliable, up to date work on a very important field of medicine is presented by Hamblen in his *Endocrinology of Woman*[2]. It is sometimes the opinion of general medicine men that gynecology and endocrinology are specialties that are employed in rare or bizarre conditions or in strictly surgical disorders. This is certainly not the case. The problems of disordered growth in adolescence, nutrition, fertility, pregnancy, the menopause and senescence are the usual, common, and fundamental problems of health and disease and, as such, concern the average physician. In other words, the material of this book is suitable for, and will be useful to, the general practitioner.

The endocrine recommendations are conservative and specific. They are based on prolonged original clinical work by the author. Articles from this group have appeared in the medical literature for many years. The text is thoroughly annotated with references to current research and each chapter carries a short bibliography of authoritative sources. A chapter on commercial endocrine preparation is included.

This book can be unreservedly recommended.

M. P. STARR.

IN the preface to the first edition of the book, *Massage and Remedial Exercises in Medical and Surgical Conditions*,[3] published in 1932, Tidy states that it was written in the hope of supplying a need for a text in massage and exercise for senior students, those recently qualified, or for junior teachers who are in training for the Chartered Society's examination.

This book does not contain any of the underlying principles, physiological effects, or techniques of massage and exercise. The material consists essentially of the indications for the use of massage and exercise used in various surgical and medical conditions.

The etiology, pathology, and symptoms of each disease or surgical condition are given briefly and the usual medical or surgical treatment is described. Other forms of physical therapy, heat, electrotherapy, and hydrotherapy are recommended in some instances. In this, the sixth edition, the sections dealing with fractures have been rewritten in order that they may include modern methods of treatment.

The book can be recommended to physical therapists who wish a quick reference for information on the indications for massage and exercise in specific medical and surgical conditions.

GERTRUDE BEARD.

[1] TEXTBOOK OF SURGICAL TREATMENT; INCLUDING OPERATIVE SURGERY. Edited by C. F. W. Illingworth, M.D., Ch.M. F.R.C.S.E. 2d ed. Baltimore: The Williams & Wilkins Co., 1944.

[2] ENDOCRINOLOGY OF WOMAN. By E. C. Hamblen, B.S., M.D., F.A.C.S. Springfield, Ill.: Charles C. Thomas, 1945.

[3] MASSAGE AND REMEDIAL EXERCISES IN MEDICAL AND SURGICAL CONDITIONS. By Noël M. Tidy. 6th ed. Baltimore: The Williams & Wilkins Co., 1944.

THE fourth edition of *The Pathology of Internal Diseases*[1], by Professor William Boyd, follows the same plan of organization as was used in the previous editions, which appeared in 1931, 1935, and 1940.

The subject matter is taken up according to organs and organ systems, as in most standard textbooks of special pathology. However, this book differs from the others in that symptomatology and physical findings are correlated with the pathologic changes. Thus, it is neither a textbook of pure pathology, nor a textbook of clinical medicine; rather, it is a combination of the two. It treats the subject of pathology as a living science, accurately and concisely, and in so doing becomes of general interest to the surgeon, internist, and pathologist, alike.

New material in liberal quantities has been added to the fourth edition. Discussions of the Rh factor in erythroblastosis fetalis, of blast injury, primary atypical pneumonia, sulfonamide nephritis, and the like, bring the book up to date. Twenty-two new figures and 4 new colored plates have been added. These greatly enhance the value of the book. The text has been shortened by 14 pages, but the material presented continues to be adequately and forcefully discussed, and is revised so as to present the newest ideas on controversial subjects. The index remains short (16 pages) and this may be considered by many to be a disadvantage.

This excellent standard textbook is highly recommended to all physicians and advanced medical students. EUGENE HILDEBRAND.

THE 24 page pamphlet *Arterial Injuries*[2] is published as a guide to medical officers in the treatment of acute vascular injuries, by a committee of outstanding specialists in this field under the chairmanship of Sir Thomas Lewis. It is intended only as a guide for early treatment and not as a treatise on definitive therapy.

The morbid anatomy, diagnosis, and development of the collateral circulation are summarized. The principles of treatment concerning hemorrhage, partial division of an artery, and ligation, management of the ischemic limb with particular attention to the patient's general condition, and the assistance of the collateral circulation, are stressed.

Diagrams illustrating the use of artificial tubes for bridging defects and the technique of anastomosis are given, together with the technique for the administration of heparin and the performance of sympathetic block.

This memorandum should serve a useful purpose "for the guidance of those who have had only limited previous experience of the early treatment of arterial wounds." D. C. ELKIN.

[1]THE PATHOLOGY OF INTERNAL DISEASES. By William Boyd, M.D., LL.D., M.R.C.P.(Ed.), F.R.C.P., (Lond., Dipl., Psych.,) F.R.S.C. 4th rev. ed. Philadelphia: Lea & Febiger, 1944.

[2]ARTERIAL INJURIES; EARLY DIAGNOSIS AND TREATMENT. By The Vascular Injuries Sub-Committee of the M.R.C. War Wounds Committee. Medical Research Council War Memorandum No. 13. London; H. M. Stationery Office, 1944.

THE introductory "Survey" by General Kirk of Vasconcelos' *Modern Methods of Amputation*[3] covers the development of amputation. Unfortunately it does not discuss the book or its author. General Kirk is recognized as one of the world's greatest authorities on the subject of amputations, especially from the standpoints of interest, enthusiasm, and experience.

Vasconcelos states plainly that his book was not intended for the expert amputation surgeon but for the person who does an occasional amputation. The reviewer questions the advisability of this point of view, except in the occasional traumatic civil case; the surgery of amputations is a specialty within a specialty. The victim is a person who is losing part of his divine endowment. He should not be subjected to the possibility of losing more than the original toll. He should be safeguarded against all the complications and results of inadequate surgery, such as neuroma, phantom limb reamputation and revisions. He should be provided with a good stump for a prosthesis.

Amputation should be done by none but the expert and experienced surgeon, with the possible exception of when the blood supply of a limb is irreparably inadequate and life is jeopardized thereby.

Amputation surgery is irreversible. There is the element of finality. The victim has lost something the Lord gave him.

The enthusiasm of Vasconcelos for his subject is genuine. His presentation is logical. His point of view is that of the practical surgeon, who is advising the general practitioner. His experience covers a 20 year period. His research has been clinical.

The object of the book is to present a group of reliable techniques for amputation of the limbs. A review of all procedures served to help Vasconcelos in eliminating the purely academic operations. Through experience gained in World War I knowledge concerning amputations has been revised and it has been demonstrated at the war veterans' centers where prostheses are applied that rehabilitation for work and adjustment to civilian life are impossible unless a well studied and perfectly fitted prosthesis can be obtained.

With 20 years of experience, it was possible to judge the value of the various techniques. After studying an extensive bibliography and after making comparisons, Vasconcelos described the operations which he believed were of real clinical value. He therefore considers his book a selective work rather than a compilation. He attempts to place a chapter of surgery within the reach of any practitioner; "something which should be known not only to those who specialize in surgery, but also to the practitioners who may be called upon to go out into the country districts, for after all, it is a chapter of emergency surgical operations, the perfect knowledge

[3]MODERN METHODS OF AMPUTATION. By Edmundo Vasconcelos. With an Introductory Survey of "The Development of Amputation" by Major Gen. Norman T. Kirk, M.C. New York: The Philosophical Library of New York, 1945.

of which is a duty for those who must watch over the health and the life of others."

The chapter on prostheses is narrowed down to the strictly essential points since the general surgeon and the practitioner must prescribe the future apparatus. The function of the surgeon does not cease with the completion of the operation; he must select the prosthesis and supervise the patient's rehabilitation, steps indispensable to good results. When amputation is definitely indicated, the surgeon should so perform the operation that the orthopedist or the limb-maker may adapt the artificial apparatus to the needs of the patient. The surgeon and the limb-maker must work in harmony.

The chapter on indications for amputation is naturally sketched in general terms since the factors contributing to the surgical indications are so many.

The author prefers to present his subject in didactic form, so that the book may be useful to a large number of practitioners; those endowed with great acumen and learning do not need it.

The book is the outgrowth of the official report submitted by the author at the 3rd Brazilian and American Surgical Congress which met in Rio de Janeiro, November, 1941. It contains so much borrowed material that it is often difficult to determine the author's particular contributions. It is noteworthy that no mention is made of such contributors to the subject of amputations as Vanghetti, Sauerbruch, Kessler, and Nissen and Bergman.

The drawings illustrating the technique are original and were done by Filho, directly from the cadaver, under Vasconcelos' direction. They are clear and instructive. There are also diagrams, many cadaver dissections, x-ray films, and photographs.

Some of the subjects covered are: indications for amputation; sites of election, technique of amputations and disarticulations; preoperative and postoperative care; and prostheses.

The bibliography lists 499 publications. There is no index but the table of contents is called the index.

PHILIP LEWIN.

THE subtitle of *Pye's Surgical Handicraft, A Manual of Surgical Manipulations, Minor Surgery, and Other Matters Connected with the Work of Surgical Dressers, House Surgeons and Practitioners*[1] explains in the clearest fashion the content and purpose of this compilation. This is the fourteenth edition of an apparently successful English work, the first having been written by Mr. Pye in 1884. Since that time numerous contributors have added to its pages so that the present volume contains terse authoritative information on a large number of surgical and related subjects.

The plan of presentation follows the modern style in that the editor has striven to present technical procedures pictorially, thus lending brevity and clarity to the written word. There are a total of 724 illustrations to be found within its 628 pages, plus an adequate index for quick reference. It reads easily because of the type style as well as the content.

The completeness of the book in relation to subjects covered is quite satisfactory, but as is the case in most such texts of minor surgical procedures its failing is a lack of detail in some sections. On the other hand, if this book is to be used only as a guide for a busy surgical house officer its proper place in medical literature will have been found. The scope of the book is indeed wide, since its details range from those of urinalysis to the postoperative management of all types of surgical patients and include the therapeusis of venereal disease as well as that of acute poisoning. The general tone of the text would lead one to believe that the procedures descril ed were the best known for the particular instance under discussion, whereas actually they represent the written plan of the particular author's own personal method. No bibliography is presented to stimulate further study. Thus one comes easily to the conclusion that the text represents local English thought on certain hospital procedures. As a result of this type of presentation, many instances are found in which American surgeons will be at variance with both the procedures and the principles set forth. For example, we cannot agree that breast tumors of doubtful origin should be removed under local anesthesia and the patient sent home to await the pathologist's report. Through-and-through drainage of a felon and other instructions on the care of hand infections are in keeping in this text only because of a complete omission of any references to the monumental work of Kanavel. The section pertaining to the injection treatment of hydrocele, varicocele, bursae, and ganglia certainly is difficult to accept. One wonders about the particular author's experience when he states that he is "astounded at the regularity with which these swellings are obliterated."

There is no doubt but that there is much merit in the text, especially since it carries to its readers the opinions that are the natural outgrowth of other medical experience. If we can assume that its contents are truly representative of English views on therapy, the procedures described can be blended with those usually employed by the reader whenever desired without the necessity of actual travel.

WALTER CARROLL.

[1] PYE'S SURGICAL HANDICRAFT; A MANUAL OF SURGICAL MANIPULATIONS, MINOR SURGERY, AND OTHER MATTERS CONNECTED WITH THE WORK OF SURGICAL DRESSERS, HOUSE SURGEONS, AND PRACTITIONERS. Edited by Hamilton Bailey, F.R.C.S.(Eng.). 14th ed. Baltimore: The Williams & Wilkins Co., 1944.

AMERICAN COLLEGE OF SURGEONS

THE BASIC MEDICAL SCIENCES IN GRADUATE TRAINING IN SURGERY

GEORGE H. MILLER, M.D., Chicago, Illinois

PROGRESSIVELY increasing attention was being given to the subject of the basic medical sciences in graduate training in surgery prior to the outbreak of war. Since that time, the pressure of war's demands on all facilities for medical education and the disruption of graduate training programs have temporarily forced it into the background. Now, with the approaching prospect of peace, it is again assuming a position of prominence. Its importance becomes even greater due to the difficulty of providing sufficient additional graduate training facilities to meet the needs of medical officers, some of whom are even now beginning to be released from military service.

The size of the postwar need has been dealt with in published analyses of the answers to questionnaires sent to medical officers in the military forces by The Committee on Postwar Medical Service (2).

Reports have also been made dealing with the possibilities of increasing the facilities for graduate training (1, 3). The need can be met only in part by increases in the number of residents in hospitals now qualified for graduate training. It will require in addition, the development of training programs in a considerable number of hospitals which in the past have not been doing graduate training. Assistance in this expansion is to be expected through the utilization of some of the larger private hospitals, selected city and county hospitals, and certain hospitals of the United States Government services. Co-operative programs are also being developed in which part of the work is obtained in the graduate training department of a medical school and part in a hospital not under medical school control.

In considering the establishment of residencies in a hospital which has not had a graduate training program, one of the problems which comes to the fore, and often is difficult of solution, is the assurance of adequate training in the basic medical sciences. This phase of training has received increasing emphasis in recent years both by the American College of Surgeons and by the Specialty Boards. The advances in medicine and surgery have made this emphasis imperative. It is natural therefore that the officers of a hospital, contemplating the establishment of residencies, want to know what constitutes adequate basic science training.

It is also important for the trainee in a specialty to have this information available. This will be even more true after the war when there will be a large number of interrupted programs to be completed. Although hospitals generally are anxious to complete the training of their internes and residents who are now in military service, the longer the war lasts the more impossible this becomes. It is certain that there will be many a young doctor who will find it necessary to complete his training program at some place other than the hospital in which he was a resident when the war brought an interruption of his training.

At the present time, one hears complaint that it is difficult for the education committee of a hospital to find any printed statement sufficiently clear and detailed to serve as a guide in formulating plans for basic science training. The same holds true for a trainee who wants to be sure of the adequacy of a program when he is making a choice of a hospital residency.

It has seemed desirable to undertake a discussion of this phase of training in order to try to arrive at a clearer understanding of what constitutes an adequate program in applied basic sciences. It is not the purpose of this discussion to arrive at a synopsis or even to outline a curriculum of the basic science work needed. Such detailed outlines must vary considerably due to the following: (1) differing needs of the different specialties; (2) difference in total length of residency (varying from 3 to 8 years); (3) differences in type of institutions being utilized for training.

It shall be the purpose, instead, to emphasize and bring into perspective the major objectives and to consider some of the means of attaining them.

PRELIMINARY SURVEYS

It is a matter of common knowledge that there is considerable variation in the programs of graduate training in surgery in different institutions which are doing excellent work in this field.

In order to make an effective approach to a consideration of the place of the basic sciences in the programs, it seemed desirable to visit a number of representative institutions. These visits were used to some extent for the obtaining of statistical data regarding differences in the programs but still more, through interviews with members of the staff who are responsible for different phases of the training, they were used to gain an idea of the developmental background behind the differences. The interviews also offered opportunity for a frank discussion of the experiences in each institution as to points of special strength or weakness, and the present trend of their efforts to improve the program.

The visits, while concerned chiefly with the larger medical schools, have not been confined entirely to these but have sampled as well the experiences of certain smaller schools and nonteaching hospitals which have been offering approved residencies. They have also been made to include a limited number of hospitals which have not been doing graduate training but are now preparing to begin it. The latter have been included in order to gain a firsthand knowledge of the special problems faced by such hospitals in undertaking this work.

Geographically, the contacts have covered the country widely in order to include any significant regional variations and trends.

The following discussion has grown out of interviews with members of the staffs of thirty-four medical schools and of twenty-five nonteaching hospitals.

HISTORICAL

It is worthwhile to note briefly the sequence of developments leading up to the present position of the basic sciences in graduate training in surgery.

The training of specialists in the field of surgery has shown a steadily increasing emphasis on the basic sciences over a considerable period of years. Fifty years ago the young doctor, serving as an apprentice or holding an assistantship in a department of surgery, was concerned chiefly with developing the best possible skill in operating. Often exaggerated prominence was given to such considerations as speed in operating and the ability to operate through extremely small incisions. Considerable attention was given to devising special suture methods and to various "trick" ways of tying ligatures.

During this period, the more energetic and progressive men holding assistantships in the better university departments of surgery were likely to seek opportunity to serve in the department of anatomy as demonstrators to the undergraduate medical classes. Some became excellent teachers of anatomy and were a source of stimulation to students by introducing examples of the practical application of the study to their clinical work. This work in anatomy has been retained by many institutions as a part of the graduate training program, though now most trainees assist in the course in surgical anatomy instead of in general anatomy. The point to be emphasized is that, at that time, work in anatomy constituted usually the only specific emphasis on basic science during the training of the surgeon.

About the turn of the century, there developed an emphasis on the value of a study of pathology by the surgeon in training. This was the result of the wider appreciation by surgeons of the fact that successful surgery is dependent not only on a knowledge of the anatomical accessibility of the lesion and on good technique but also on a full knowledge of the "life history" of the disease process. Whether in the realm of inflammation or of neoplasm or of other surgical conditions, the surgeon wanted to think beyond the immediate anatomical lesion and understand fully its near and remote effects and sequelae.

For a time, in the field of training, pathology was regarded more or less as an interloper and a competitor of anatomy. One heard at times heated discussions as to which of the two should be chosen by the prospective surgeon as his field of basic science work. After a relatively few years, these arguments practically disappeared. The ambitious trainees were adding pathology and retaining anatomy by giving a reduced amount of time to the dissecting room.

Some professors of anatomy resisted at first the reduction of the demonstrator's time but before long both pathology and anatomy were sharing in the basic science attention in most good programs of surgical training. A limited attention to bacteriology was sometimes included with pathology.

More recently, with the extended use of surgery in the reconstructive field, where physiological considerations are prominent, and with the development of corrective surgery in certain abnormal physiological states, physiology and biochemistry have been brought prominently into the training picture. Also, new developments in the field of anesthesia, requiring discriminating choice and foreknowledge of potential complications, the improved handling of shock and of preoperative and

postoperative management, together with all the new advances in the control of infection, have brought physiology, biochemistry, bacteriology, and pharmacology all into a position of increased interest for the surgeon. One might even add parasitology to the list out of deference to those surgeons who are dealing constantly with such conditions as hydatid cysts, amebic abscess and elephantiasis. Thus, it is evident that surgery has grown steadily into a closer relationship with practically the whole field of the basic medical sciences.

THE OBJECTIVES

In seeking an answer for the question of the hospital committee or of the trainee, referred to above, it is necessary to visualize as clearly as possible the objectives toward which the basic science work of a graduate training program in surgery is directed. These objectives may be variously expressed and must be permitted a certain variation of emphasis in different institutions and under varying conditions.

However, the broad general objective of graduate training in these specialties is to provide for the country the highest level of surgical care by furnishing, under competent instruction and supervision, the best possible training in both surgical skill and surgical judgment.

Another objective is the development, in the future specialist, of a scientific interest and background which will make him capable of using such opportunities as may be present in his work for contributing to the advancement of medical science.

The emphasis on the basic medical sciences in the training program, while directed toward the broad objective referred to, bears most heavily on that which is regarded by many as the more important and more difficult phase of training—the development of surgical judgment. For this, it must be *applied* basic science. It is applied in many ways but especially in the scientific study of patients and in the acquiring of a clear understanding of the fundamental interpretations of clinical phenomena in the special field. Developed in this way, the basic sciences are removed from the status of review work and should be of real graduate caliber. They also take on a new interest by revealing a threefold goal—thorough training, improved care of patients, and contribution to science.

Some unfortunate misconceptions have arisen from failure to regard the applied basic sciences as advanced work at a graduate study level. Following are the misconceptions most commonly met:

1. Review courses are needed because the resident has forgotten details of his undergraduate courses.
2. The basic science requirements of the College and of the Specialty Boards are academic hurdles which require special basic science study to clear but are of no further concern.
3. Lectures by a preclinical teacher can cover failure of the clinical staff to make adequate application of basic sciences.
4. Basic science requirements can be met by giving the resident training in the techniques of the diagnostic laboratory of the hospital.

Let us consider, in turn, each of these misconceptions:

1. *Need for review courses.* Certainly the resident will have forgotten details of his undergraduate work and review study is necessary. This, however, is not done best in formal review courses. He should be obliged to review in order to meet the demands of the advanced work of his training program. Such demands may consist in assigned participation in well organized seminar programs and clinical conferences and should be evident also in ward rounds and in clinics if these are kept at a high instructional level. The latter is illustrated by the answer of a resident when asked about attention to anatomy. He said, "We don't have any review course but 'The Chief' gives a real quiz in anatomy as a part of his discussion and questioning at each operation and we sure have to review all the time to keep up with him."

In general one may say that the demand for review should be inherent in the well organized graduate training program, but formal review courses of undergraduate work should not constitute a part of the schedule.

2. *Treating basic sciences as hurdles.* The idea that the basic sciences are hurdles is not entirely in error. Certainly as requirements for qualification, they assume this character. The error lies in treating them as nothing more than hurdles when in reality, meeting these requirements should be evidence of an established quality in professional work and development. The erroneous attitude is illustrated by the tendency of some candidates for qualification to go to the head of a preclinical department saying, "I am going to take the ——— examination this spring. I want you to get me ready for it during these next three weeks." Professors will usually try to give assistance in response to such requests though expressing doubt of the permanent value in many cases. Such a period of study is an opportunity of real value. The error occurs when the candidate treats it as mere cramming for an examination.

Likewise, some hospital committees seem to have regarded the basic sciences as merely awkward requirements which must be met.

This regarding of the basic sciences as mere hurdles and the reliance on "cramming" for examinations should steadily diminish as more and more emphasis is placed on the application of these sciences to the daily work of the clinical specialist.

3. *Use of undergraduate lectures.* The suggestion is sometimes made by the educational committee of a hospital that they will meet the basic science requirements for residents by having them attend the undergraduate lecture courses in a nearby medical school or sometimes by arranging for professors to give special short courses in those preclinical subjects. To say that this is unsatisfactory is no reflection on either the professor or on his undergraduate course.

The difficulty is that such undergraduate lectures are not applied basic science, nor are they graduate work.

If a hospital is to use university courses to supplement its training program in the applied basic sciences, such courses should be given by teachers prepared for this graduate work and having a knowledge of the clinical problems sufficient to permit them really to present the application of the basic sciences.

4. *Training in diagnostic laboratory.* The question of filling the basic science requirements by assigning the resident for a period of training in the diagnostic laboratory can be answered by recalling the main objectives of the resident's training program. It is not reasonable to use his time for training as a laboratory technician. His knowledge of the more elaborate procedures of the laboratory should be such as to emphasize their range of usefulness, and also their limitations, in his field. It should thus enable him to make more effective use of laboratory work in his clinical decisions.

Exceptions will, of course, arise, as in the case of a resident who is engaging in a research problem dependent on certain clinical laboratory tests. He will need thorough understanding of those procedures and can usefully work in the clinical laboratory as an integral part of this special program.

The principle governing the relationship of a resident to the diagnostic laboratory should be a recognition of the fact that he is there primarily for training in applying laboratory findings to patients and only secondarily, or in a research capacity, to take part in the technical work of the laboratory.

DIFFERENCES IN APPROVED TRAINING PROGRAMS

Differences in total length of training period. The length of time which has been adopted by the Department of Graduate Training of the American College of Surgeons and that required by most of the Specialty Boards for surgery and the surgical specialties as the minimum for the institutional phase of training is three years after an approved interneship. In the larger teaching hospitals the length of residency varies all the way from three to eight years. Approximately half of those included in this study were found to have surgical training programs of five or more years' duration while the other half have programs lasting either three or four years.

At times in the past there has been some difference of opinion as to the relative merit of the shorter graduate training programs. It should not be regarded as reopening any old controversy to take the position at the present time that the new residencies to be developed in the effort to meet the postwar training load will fall, for the most part, in the second group and will be of three or four years' duration. For this reason, the following comments should be regarded as referring especially to the facilities for, and possibilities of, this group.

This is not overlooking the value and the necessity of training beyond the three or four year period. The ultimate aim should be accomplished effectively with a wider recognition that the years immediately following completion of a three or four year program are a continuation of training while holding a "limited responsibility" appointment.

Variation in content of the training programs. The institutions studied showed variation not only in length of training program but also in content. Over many years their accomplishment shows, however, that this considerable variation of program is not inconsistent with excellent results. In reality, such flexibility is desirable as permitting the best utilization of the differing facilities of institutions, both in material and in staff. A certain flexibility should also be utilized in developing most effectively the special scientific aptitudes and interests of the trainee. It should be remembered, however, that the range of variation which may be appropriate in programs of six to eight years' duration is much reduced when one deals with a three or four year program.

Time devoted to the basic sciences. Confusion has sometimes occurred because of two different interpretations of this. Some have discussed it as referring only to those parts of a residency during

which the resident is released from responsibility for patients and devotes himself solely to one or more of the basic sciences. Others regard it as including all those places throughout the whole training where application of basic sciences is emphasized. The latter is a very important part of the program. In fact, the permanent value of the basic science work is dependent to a large extent on the degree to which the clinical staff makes constant application of the basic sciences in its discussions and work. This teaching, however, is incorporated so intimately with the clinical training that it fails to appear in a time record. Seminars and teaching conferences are also an important means of emphasizing certain of the applied basic sciences and these likewise do not appear in any listing of time devoted specifically to those sciences.

The above distinction must be taken into account in the formulation of a graduate training program and adequate provision must be made for both phases of emphasis on the basic sciences.

In some of the hospitals which have residencies of six or more years, it is customary to have assignments totaling as much as eighteen months or two years devoted primarily to the basic sciences and research. Obviously such a program is not applicable to hospitals which devote only three or four years to the whole residency. In the latter group of hospitals, the time devoted entirely to the basic sciences must be considerably shorter. Usually, it varies between six and twelve months. This shorter amount of time reduces correspondingly the range of flexibility in that part of the program.

What basic sciences should be included? As an introduction to a discussion of the basic sciences to be included, the following excerpts are quoted from the published requirements of the different boards for surgery and the surgical specialties and of the American College of Surgeons.

Surgery. "This period of special training shall be of such a character that the relation of the basic sciences of anatomy, physiology, pathology, bacteriology, and biochemistry is emphasized. Knowledge of these sciences as applied to clinical surgery will be required in the examination."

Orthopedic surgery. "He must have knowledge of the basic medical sciences related to orthopedic surgery."

Neurological surgery. "This period of training shall be of such a character that the relation of the basic sciences of anatomy, physiology, pathology bacteriology, and biochemistry is emphasized. Knowledge of these sciences as applied to the practice of neurological surgery will be required in the examination."

Plastic surgery. "The period of training shall cover . . . and the basic sciences of anatomy, physiology, pathology, bacteriology, and biochemistry as they are related to plastic surgery."

Urology (a). "This period of specialized training should include graduate training in anatomy, physiology, pathology, and the other basic medical sciences which are necessary to the proper understanding of the disorders and treatment involved in the specialty of urology."

Obstetrics and gynecology. "Each candidate should have certain fundamental knowledge of the basic essentials of anatomy, pathology, bacteriology, physiology, pharmacology, and therapeutics as related to the practice of obstetrics and gynecology."

Ophthalmology. "This shall include (applicable so far as possible after 1944) graduate study of the basic medical sciences, which are fundamental to the intelligent practice of ophthalmology, particularly; anatomy, histology, embryology, optics, physiologic optics, visual physiology, and psychology, pathology, bacteriology, pharmacology, disorders of ocular mobility and binocular vision, perimetry, and the skillful adjustment and use of instruments."

Otolaryngology. "A candidate must have completed an acceptable basic science course."

American College of Surgeons. "The resident staff shall be required to observe and participate in autopsies, to devote adequate time to the study of gross and microscopic pathology, to acquire a degree of practical knowledge of clinical roentgenology and radiology, to pursue anatomical studies by dissections on the cadaver and animals, to participate in clinical or experimental research and to devote definite time to other study of the basic medical sciences.

"If not available within the hospital, provision for adequate collateral study of the basic medical sciences shall be provided through affiliation with another hospital or educational institution."

The above quotations amply bear out the statement made in the beginning as to the increased number of basic medical sciences which have become of importance to the surgical specialists.

It is also evident why hospital committees have felt some uncertainty as to the best way to utilize the time at their disposal for basic science work.

It is important in this connection to recognize that, for certain of the basic sciences, an emphasis on their application in the surgical training program can best be made in connection with the clinical work. For these, the trainee does not have to be detached from his ward service and devote his entire time to the basic science concerned. There are others, however, which are most effectively dealt with by making them the sole, or at least the primary, responsibility of the resident for a definite period of time. Those not

receiving a separate time allotment must not be regarded as lacking in importance.

The most common special assignments of time for the basic sciences are to pathology and anatomy.

Pathology. Since many of the surgeon's decisions depend closely on his personal knowledge of pathology, this subject becomes the one most urgently requiring an individual assignment of the resident's time. There is practically unanimous agreement on this. The hospitals with long training programs in many cases allot a whole year to pathology while those with shorter residencies commonly reserve six months primarily for this work.

In addition to this period of concentrated attention to pathology it is, of course, essential that the resident throughout his whole training should continue to study the pathological material from his service. In a surgical service which has its own department of surgical pathology this is easy. In others, the necessary daily or frequent contacts with the department of pathology must be maintained. A few surgeons have voiced the belief that the latter type of study of pathology can be made sufficiently thorough alone to serve for the resident's training in this subject. Most, however, think that this type of divided responsibility cannot produce as good a result as when combined with a period of full-time service in the department of pathology. Another advantage in the assignment to pathology lies in the opportunity during this time of carrying on or of collaborating in a research problem in this field. The experience in exhaustive reading in the field of his research problem and the need for discriminating evaluation of the work of different contributors to its literature are an invaluable element of this part of his training.

Anatomy. Often a special assignment of time is made also for the study of anatomy. This is true in about half of the programs surveyed. Two surgeons placed anatomy as more important even than pathology in the study program. However, this was more than offset by the opinions of many professors of surgery who think the time can be better utilized if careful attention is given to pointing out anatomical considerations and to quizzing prior to and during operations and in the autopsy room, thus allowing studies on the cadaver to be reduced to a relatively small number of special regional dissections.

While a separate allotment of time for work in a department of anatomy is desirable, and is possible in the longer training programs, it would seem that the necessary emphasis on this subject can be otherwise provided in a well organized training program. In this case, however, it must be definitely included as a teaching responsibility of the surgical department.

Bacteriology, physiology, biochemistry, and pharmacology. Applied bacteriology will usually be included to some extent during the period devoted to pathology. In general, however, all of the above group of subjects are applied so continuously in the daily work of the resident and are such an essential part of the study and treatment of his patients that the clinical work of the hospital becomes the place where the advanced study of these subjects must be centered. Every ward round and conference must stress one, or several, or all of these, according to the variety of the cases presented. They should also be given special and detailed application in seminars planned for that particular purpose.

The use of specialists from preclinical departments and from other clinical departments, who are qualified for this teaching, is a necessary part of the program but they should be regarded as "consulting specialists" and "contributors" and not used as a means of relieving the clinical staff of their continuous responsibility. The residents' research work also, whether clinical or preclinical in origin, will require advanced study in one or more of the basic sciences.

The important broad consideration here is that the application of these sciences to the study of disease in patients should be real graduate work for which the clinical departments must carry a large share of responsibility.

Use of teaching assignments in preclinical departments. In the longer residencies, an assignment to assist in a preclinical department can sometimes be used to advantage, since the liberal time available allows the resident to engage in research and advanced study as well as to assist in teaching. In the shorter residencies, the brief time available for such assignment is likely to be entirely occupied by a heavy routine teaching program. This creates a danger that the resident may become only a borrowed teaching assistant instead of a member of the graduate training group of that department. Preclinical teaching assignments should be used only when the training value for the resident obviously compensates for the time allotted to the department.

Research. The value of research as a means of stimulating study in the applied basic sciences should be utilized in the graduate training program. Only the longer programs can allot a large segment of time, for example, to the bacteriology laboratory for a study of infections or to some

other laboratory for experimental work in that field. Nevertheless, it is possible and necessary even in the shorter programs, to stimulate an inquiring attitude of mind and to encourage and guide the resident in investigative work on some problem of particular interest to him.

Co-operative programs. Some hospitals, recognizing their weakness for training in the basic sciences, have corrected the defect by appointing to the staff men specially qualified for this work.

Other hospitals which face a similar difficulty but are unable to apply the same solution should seek to develop a co-operative program with the hospital of a convenient medical school or with a graduate school of medicine which gives a fully approved graduate training program. The following illustrate different forms of co-operative effort already being used:

1. A co-operative program is arranged with the hospital of a medical school under which part of the residency is spent in each of the two hospitals. Three year programs divided on both 2:1 and 1:2 ratios are being employed. Two years in each hospital is a proposed improvement.

2. When a medical school is near at hand, a program may be planned by which the residents can have access to certain of the applied basic science facilities provided for the surgical residents of the university hospital.

3. Arrangement may be made for the resident to spend one year in the combined applied basic science and clinical program of a graduate school of medicine which offers a fully approved graduate training program.

4. Arrangement may be made for selected members of the staff to become temporarily adjuncts to the teaching staff of a university hospital to gain a broader scientific background and a better familiarity with graduate training methods.

5. A hospital may secure the assistance of guest teachers. This refers not to the usual series of visiting lecturers, but, as one hospital's plan employs it, a ten-day, full-time visit during which the guest takes part in ward round discussions with the staff as well as in the conferences and seminars for residents. Additional forms of co-operative effort will doubtlessly be devised as medical schools and hospitals continue to work and plan together for the best utilization of their combined resources for graduate training.

The foregoing discussion has dealt with the basic science requirements in a broad way and in the light of the immediate postwar training needs. It has not dealt with strictly one-department questions such as the need of ophthalmology for special courses in physics of optics and physiology of optics nor of otolaryngology's similar need with reference to sound. Likewise, the big question of need for a greater responsibility on the part of medical schools for graduate education in the clinical fields has been omitted.

It is hoped that the discussion may be of assistance to certain hospital staff groups, who desire to undertake graduate training, to evaluate their resources, and to take the necessary steps to organize a strong training program.

REFERENCES

1. COLWELL, A. R. J. Am. M. Ass., 1945, 127: 741–746.
2. LUETH, H. C. J. Am. M. Ass., 1944, 125: 1099–1103; 1945, 127: 759–770.
3. REYNOLDS, C. R. Surg. Gyn. Obst., 1945, 80: 655–662.